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An organismic approach to the development of a comprehensive science curriculum.

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AN ORGANISMIC APPROACH TO THE DEVELOPMENT OF A COMPREHENSIVE SCIENCE CURRICULUM

A Dissertation Presented

By

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DEDICATION

To My Dearest Parents

for their unfailing love

and inspiration

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ABSTRACT

An Organismic Approach to the Development
of a Comprehensive Science
Curriculum

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There is no doubt that science education is considered to be an important element in the lives of children. Numerous innovative attempts over the last ten to fifteen years have contributed greatly to improving the quality of science instruction in elementary schools. Even though the progress that has been made is encouraging, there is a growing concern that the field of science education as a whole requires a philosophical and theoretical perspective that can guide the development of curricula, the preparation of teachers, teaching strategies and evaluation. Such a philosophical and theoretical scheme can then serve as the integrated system around which the teaching of science can be organized.

This dissertation addresses the issue of science curriculum development based on the organismic philosophy and theoretical framework of the Anisa Model. From an

organismic perspective the justification for any curriculum is that it should sustain the actualization of human potential. A natural science curriculum can foster children's understandings about the physical world so that the resultant actualization of their potential can be organized around the attainment of technological competence. This means that children will gradually begin to understand, discover and apply the laws and principles of natural science in such a way that the quality of life can be continually improved. The primary goal of the natural science curriculum, then, is the development of technological competence in interacting with the physical environment.

The purpose of this dissertation is:

(1) To investigate the extent to which an organismic philosophy is consistent with contemporary advances in the field of natural science.

(2) To interpret the role of natural science in human growth and development from an organismic perspective.

(3) To show how an organismic philosophical perspective can guide the development of a possible theoretical framework for a natural science curriculum, the goal of which is the attainment of technological competence.

(4) To indicate the way in which an organismic view addresses the issue of integrating natural

science with the overall curriculum.

(5) To set forth the distinguishing features of the proposed theoretical framework based on an organismic perspective in comparison with other science curricula that have been developed.

The proposed framework for the natural science curriculum includes a detailed outline of the most fundamental laws and principles of physics, chemistry, biology, geology, astronomy and ecology, together with a description of the psychomotor, perceptual, cognitive, affective and volitional processes that are involved in the attainment of technological competence.

From a functional point of view, the proposed framework may be used to prepare teachers to teach science and/or to generate learning experiences in natural science for children.

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CHAPTER I

SCIENCE EDUCATION: STATE OF THE FIELD

It has only been within the last one hundred years that science has become a necessary and legitimate component in the public school curriculum in the United States. The first innovation in elementary school science according to Rosen (1963) was the introduction of geography in the Boston schools and this led to the creation of a new industry in 1784--the manufacturing of scientific apparatus for schools. The real entry of science was felt with the rise of the Pestalozzi object teaching movement in the late 1850's (Smith, 1963). Objects were placed before children to develop their perceptive faculties. For example, they had to name the object, describe its parts and state the relationships among the parts. At about the same time (1870's) the writings of Herbert Spencer were becoming popular, particularly his essay "What Knowledge is of Most Worth?" which pointed to the overwhelming importance of science in the school curriculum (Showalter, 1975; Smith, 1975). The influx of new views on science spurred American universities to announce the acceptance of physics and chemistry toward entrance requirements. By the early 1900's elementary school science was established as nature study.

The modern trend towards teaching science as inquiry rather than passive observation has its roots in the philosophy of pragmatism as espoused by William James and John Dewey. In the 1920's, Dewey's emphasis on the knowledge of the methodology of science as a valuable tool for the growing child ousted the traditional nature study approach (Dewey, 1966).

Integration of the processes of inquiry and the accumulated knowledge of science in a curriculum has been a continuous concern for the National Society for the Study of Education (NSSE). An important first step by NSSE was the publication of the Thirty-first Yearbook in 1932 which was devoted to A Program for Teaching Science emphasizing integrated science teaching. In 1947, the Forty-sixth Yearbook, Science Education in American Schools, focused on attitudes, values and affective factors as they related to science and society. The most recent document, the Fifty-ninth Yearbook (1960) on Rethinking Science Education stressed critical thinking, scientific process and inquiry.

Since 1960, the National Science Teachers Association has organized numerous committees and conferences to investigate and articulate position statements on science education in relation to goals, teaching methods, curriculum innovations, teacher education, evaluation and research procedures. The aim has always been to continually upgrade the quality of science teaching so that there is meaning and relevance for the child.

Science Boom of the Sixties

The major impetus to science teaching in schools was the launching of Sputnik by the Russians in 1957. Science education in the U.S. blossomed as a direct reaction to Sputnik (Saadeh, 1973) and the U.S. Office of Education, the National Science Foundation and other public and private organizations funded heavily projects on science curriculum innovation. During the years 1960-1970, elementary and secondary school teachers witnessed what Brandwein calls "the Revolution in Science Teaching" (Rosen, 1963) or what is now referred to as "the science boom of the sixties." Fontaine (1970), in reviewing some of the federal programs for the improvement of school science and mathematics states that during the fiscal year of 1969, over 400 projects at the pre-college and undergraduate levels were supported by the National Science Foundation at an estimated cost of $142 million. In the Ninth Report of the International Clearinghouse on Science and Mathematics Curricular Developments Internationally (1975), Lockhard presents a survey of K-adult science curricula for the years 1956-1974, a span of 18 years during which science education programs mushroomed all over the world. A reworking of his data reveals the following:

Continent	Numbers of Curricula Developed 1956-1974
Africa	15
Asia	50
Australia	17
Europe	87
Latin America	17
North America	206
Total	392

Of the 206 curricula in North America, 201 were developed in the United States. Many of the curricula started at Kindergarten and went through to adult levels. Considering the tremendous significance of early childhood education, it is noteworthy that not a single curriculum was developed specifically for the preschool level in those 18 years.

A comparison of Fontaine's figures of 400 projects in one year and Lockhard's data of 201 curricula over 18 years shows quite a difference. Possible reasons for such a large discrepancy could be that (1) many of the questionnaires sent out in Lockhard's survey were not returned by the individuals or curricular organizations who had developed programs, or (2) many of the curricula developed in 1969 were short-term projects which no longer exist. If factor (2) is indeed a possibility, then the expenditure of vast sums of money on short-term operations has to be accounted for more seriously. It could be that funding agencies are aware of the problems as no new science curricula have been appearing in the last few years.

New Elementary School Science Curricula in the United States

The new science curricula were developed by numerous agencies, teams and individuals who held widely differing philosophical and theoretical perspectives about the organization of the subject matter, the emphasis on the processes of science, and the attitudes and values to be inculcated in the child. In an attempt to demonstrate the unity of science, various concepts were proposed as being the fundamental realities of natural science.

In 1966, the Educational Policies Commission published a report entitled "Education and the Spirit of Science" which outlined seven values that undergirded the whole scientific enterprise, e.g., values such as longing to know and to understand; questioning of all things; demand for verification; consideration of consequences.

Livermore (1964) of the American Association for the Advancement of Science, indicated that there were fourteen processes that characterized the method of scientific investigation. Processes such as the following were emphasized: observing, classifying, inferring, hypothesizing, formulating models.

In 1964, the National Science Teachers Association documented a Theory into Action paper in which seven major conceptual schemes were set forth as the unifying principles that cut across all of natural science. The schemes were outlined as a guide to curriculum planners in the elementary and secondary school. Most of the statements were written in terms of matter and energy. For example, all matter is composed of units called fundamental particles; units of matter interact; matter exists in the form of units which can be classified into hierarchies of organization. Since the schemes were outlined in accordance with physical science concepts, the proposed guide became a controversial issue.

Bentley Glass (1965) vehemently opposed the seven conceptual schemes, particularly from a biologist's point of view. He stated that it was not possible to express adequately the unique characteristics of a living organism by referring solely to matter and energy. The present-day debate on reductionism is an expression of the same sentiment. From a psychologist's standpoint, Ausubel (1964) criticized the new matter and energy approach as being too philosophical and too general for elementary and secondary school students.

A counterview to Glass and Ausubel was presented by Shamos (1966) who felt that the conceptual schemes of science reflected the greatest intellectual achievements of man and as such should be the focal point of the curriculum. Shamos then became the principal director of the Conceptually Oriented Program in Elementary School Sciences (COPES) which was based on the seven conceptual schemes. It is worth noting Ausubel's criticism in relation to the following statement by Shamos in the preface of one of the curriculum units on the Conservation of Energy Sequence:

> The materials require some sophistication in science on the part of the teacher, a sophistication which the average elementary school teacher does not have. Consequently, we suggest that only science specialists or teachers with more than the usual background in science consider trying this curriculum . . . (1967:iv)

The notion of identifying unifying principles in science is valid and worthwhile. Conceptual schemes do aid in focusing on what is most important in science content, but the manner in which they are stated should reflect the distinctive features of the physical and life sciences.

In an effort to show that curriculum development is a continuous process, the National Science Teachers Association (1971) issued a revised position statement on school science education for the seventies. Helpful recommendations on goals, values, process and content are presented as ideas to be considered when planning a curriculum. Many of the new science curricula of the sixties reflect a diversity of approaches in relation to selection of content and process. The goal has been to show the unity of science but in some curricula this is difficult to discern because of the great emphasis that is placed on either content or process.

Hurd and Gallagher (1968) review twelve of the most well-known science and mathematics curricula in their book New Directions in Elementary Science Teaching. The three programs that have been used most widely are the Elementary Science Study, the Science Curriculum Improvement Study, and Science--A Process Approach. A brief overview will illustrate the general thrust of each program.

The Elementary Science Study (ESS) does not appear to have any specific philosophy or theory of learning supporting it. However, it does not seem to be psychologically unsound or scientifically trivial. Children are viewed as natural scientists and allowed to explore and manipulate materials according to their own inclinations and needs in an unstructured manner. The main purpose is to motivate children to explore the world. Much of the philosophy and psychology of Piaget, Dewey, Hunt, and Berlyne are evident in ESS even though it is not explicitly stated (Rogers and Voelker, 1970).

The Science Curriculum Improvement Study (SCIS) has been guided by the work of Robert Karplus (1964; Karplus and Thier, 1967). The goal of the SCIS is the development of scientific literacy through the provision of scientific activities in the early elementary school (Thomson & Voelker, 1970). The program focuses on the conceptual framework of science as being the most crucial aspect about which children should learn. SCIS has been guided and influenced by the recent developments in psychology and reflects the ideas of Dewey, Piaget, Bruner, and Almy (SCIS Teachers Handbook, January 1974). The approach to the teaching of science appears to be well-planned and educationally sound.

Science--A Process Approach (S-APA), as its name implies, is designed to teach the processes of science to children. The cumulative learning model of the psychologist Robert Gagne has guided the development of this program (Gagne, 1963 and 1966; Livermore, 1964). The major principle is the learning of generalizable process skills which may be transferred across many subject matters.

Effectiveness of the New Science Curricula

What has been the impact of the new elementary science curricula? Innumerable research studies have investigated the effects of the most popular science curricula such as ESS, SCIS and S-APA on children's interests and cognitive abilities, teaching styles and methods of teacher education. It would be impossible to mention all these studies. A variety of research surveys summarize a great deal of information: Dunfee (1967); Gallagher (1972); Reichard (1973); Saadeh (1973); Rowe and deTure (1975) and Voelker & Wall (1976).

According to Rowe and deTure (1975), editors of the Science Education Information Report, the results of many of the research studies indicate the positive effects of the new approaches of teaching science on young children. Most of the programs developed over the last ten years help language, logic and interests to grow among disadvantaged and handicapped children. These groups of children benefit during the first three years of school from activity-oriented science. Middle and upper class elementary school children show relatively less benefit as the programs stand at present. Many of the early science curricula focus on sorting, classifying and ordering, etc., which are valuable learning experiences for the disadvantaged child whose environment may lack opportunities for these kinds of interactions. The authors suggest that the disadvantaged children who are usually denied science because they need to "catch up on basics" should be given more science. Programs that are more challenging have to be developed for the advanced primary grade students.

Many of the programs are organized in detailed scope and sequence charts with particular activities for each grade level. Even though the new curricula are developmentally-based to some extent, teachers do not appear to have a great deal of flexibility or experience in individualizing instruction, especially with the more advanced child. Scope and sequence charts are useful because they reflect systematic and careful planning but they have the disadvantage of introducing rigidity.

The positive results of some of the research in science education has helped to provide answers to some specific issues that have been of concern to science educators. However, the overall conclusions drawn by the authors of research surveys and appraisals of the future direction of the new curricula are disappointing.

Rowe and deTure (1973) conclude that the quantity of research efforts in elementary school science has fallen off. Also, relatively little information is available on the cumulative impact of four to five years of elementary science. The authors state that even though many school districts have now had almost four to six years or more of exposure to and experience with some of the new projects, very little research is being published on the long-term effects of science instruction. This kind of evaluative information is vital in assessing the worth and the appropriateness of science programs. Curriculum developers, in the early years of innovation, complained that the types of attitudes, values and processes of inquiry which they were trying to develop would take time. Although ample time has elapsed, no long-term gains have been demonstrated.

Livermore (1968), who was involved in the development of Science--A Process Approach, reiterates the fact that the proponents of many of the new programs profess either explicitly or implicitly that their approaches should foster an enthusiasm for and understanding of science that should continue beyond high school. However, little has been done to determine whether, and if so, to what extent these programs do indeed have such an effect.

Saadeh (1973), in an extensive review of the research on the direction of the new science programs, presents a pessimistic survey. He tries to assess curriculum development, the effectiveness of science curricula, instructional procedures and teacher-training programs. The studies that Saadeh cites are impressive and the immediate reaction is to say that the situation really cannot be that hopeless. However, the reality of the situation cannot be ignored. Many critics attack the new science curricula particularly on the score of how they were developed. In an evaluative report on curriculum development in science, Herbert Smith notes that

> For more than a decade, professional scientists have been almost exclusively responsible for national curriculum reform. Their influence is evident in the emphasis on the structure of science, the cognitive and abstract aspects of the discipline, the difficulty of the material, the grade level at which abstract concepts are introduced, and laboratory and inquiry experiences. The wisdom of some of the new emphases was questioned by a few skeptics, but the scientists' judgments were uncritically accepted for a time, even strangely enough, by most science educators. (1969:398)

A similar sentiment on the "crises of principle in curriculum" was echoed by Schwab. He found that out of five widely-used high school science curricula, four were controlled and developed by subject matter specialists such that the educators' contribution was negligible and that of curriculum specialists "near the vanishing point" (1970: 19). In elementary school science programs, a psychologist was the guiding force in S-APA but again curriculum specialists were not included. The ESS program was greatly influenced, in an advantageous manner, by educators who had some expertise in curriculum development.

The criticism that scientists influenced the development of programs more than curriculum specialists has some merit to it, particularly when one considers surveys that indicate the decrease in science achievement in elementary and secondary schools. Saadeh (1973) cites various authors who charge that many curricula emphasize science as an end in itself rather than pointing out the value of science in solving social and practical problems. They urge that the subject matter should be made more relevant to the needs of the student and not only geared to the academically superior student. Scientific literacy does not only mean the intellectual understanding of science, but also learning how to apply the principles of science to problems that are encountered in everyday life and to the persistent challenges that beset mankind.

That the new science curricula have not had the impact they were expected to have was shown in a recent survey conducted by the National Assessment of Educational Progress (NAEP). Ahmann et al. (1975) cite the results of the survey. It was found that the knowledge of fundamental scientific facts and principles declined among young American students between the years 1969 and 1973. Comparing the results of the 1969-70 and 1972-73 national assessments of science indicates that 9-year-olds, 13-year-olds, and 17-year-olds tended to perform less well in 1972-73 than their counterparts had about three to four years ago. The questions in the survey covered four broad educational goals of science: knowledge of basic facts and principles of science; the processes of science; understanding the investigative nature of science and attitudes about the value and appreciation of science. Achievement declined in the biological and physical sciences, but the greatest drops were in the physical sciences. It was notable that the performance of black students did not improve at all three levels, whereas some extreme rural and South-eastern groups did improve relative to national norms. Another noteworthy finding was that the science performance of girls has not improved, but appears to be declining at about the same rate as the boys. In assessing the results of the survey, Ahmann et al. conclude that the downward trend of science performance may only reflect the unusual emphasis that was given to science education in the wake of Sputnik. The results 1972-73 may really indicate a return to more normal levels of achievement which probably existed before the 60s. Since we live in a scientific and technological age, the concluding remarks of the authors should be of grave concern to educators:

> We must decide whether the observed decline in science achievement can be tolerated, or, quite to the contrary, whether we should reject even a "steady state" and insist upon improved levels of science achievement during the next four years. (Ahmann et al., 1975:25)

It could be that the decline of enrollment and achievement in the physical sciences, especially at the high school level, may be related to the complexity of the ideas and the lack of input by curriculum specialists and educators in many of the new science curricula. Many authors have recently documented the problem in the physical sciences (Bates, 1975; Ignatz, 1975; Rowe, 1975). Bates states that between 1948 and 1964 the proportion of twelfth-grade students enrolled in physics in the United States dropped from 26 percent to 19 percent. By 1971 only 16% of senior students were choosing physics--less than one student in six. Reasons for the decline appear to revolve mainly around the abstract nature of physics concepts which students have difficulty in understanding. Because students are in high school, they are assumed to be in the formal operational stage and capable of dealing with abstract ideas. However, preliminary evidence from studies by Renner and Stafford suggest that only 30-50% of high school age students in the United States function at the formal operational level (in Bates, 1975). A solution to the problem has been the inclusion of more concrete manipulation of materials while studying abstract concepts.

Another area of apparent inadequacy in the new science curricula has been in the effectiveness of "process education." The goal of many new programs was to teach children the processes of science, i.e., the processes of inquiry which are considered to be the basic tools of the young scientist. Cole (1972) in a book on '<u>Process Education</u>' tries to assess to what extent the process-oriented curricula have been used, what changes they have effected in educational practice and whether they realized their potential. His conclusion is discouraging--not much has been done with the new curricula of the sixties. Cole cites John Goodlad, who after an extensive survey of educational practices, says that the process-centered innovations have been "blunted on the classroom door" (Cole, 1972, p. 20). Unfortunately, classroom practice has changed little--the needs of the children are not being met emotionally or socially, lessons are dull, boring and meaningless, teacher-directed learning from authoritative textbooks and workbooks are still prevalent. In a similar vein, Lippit observes the brute fact that

> Our research is now rich with examples of opportunities provided, but nothing gained; with new curricula developed, but lack of meaningful utilization; with new teaching practices invented, but nothing spread; with new richer school environments, but no improvement in the learning experience of the child. (in Cole, 1972:20).

Writing specifically about the program Science--A

Process Approach, Saadeh (1973) cites research which indicated that the attempt to teach science from a pure process approach results in a spottiness and somewhat incoherent presentation. This particular science program focuses on process to such an extent that the learning of content is incidental. Process and content are subject to developmental considerations and systematic organization.

Commenting on the effectiveness of teacher-training in the new science projects, Herbert Smith, a former president of the National Science Teachers Association, appears as a harsh, but realistic critic. In considering the largest and most expensive in-service program in the history of science education, the National Science Foundation Institute Program, Smith states that

> These institute programs were viewed at their inception as emergency arrangements. Unfortunately, the history of such government activity is that the emergency structures take on the character of permanent fixtures. . . . It still remains to be demonstrated that the institutes have had a high degree of effectiveness. (1966:800).

It is revealing to discover that science educators were essentially excluded from effectively participating in the NSF Institute programs. Smith goes on to point out that millions of dollars were expended to partially educate scientists in the fundamentals of public education and the needs of teacher education programs. Not many authors are as forthright as Smith in exposing the political factors that influenced the science innovations of the sixties after the launching of Sputnik I. In trying to keep pace with the Russians, the child who was being educated was for the larger part by-passed and the focus fell upon the new curricula. The priority in the educational process has to be the nature of the individual who is being educated--new curricula, new methods of teaching, teaching machines, audio-visual aids and facilities are all secondary factors, necessary but not sufficient in upgrading the quality of education.

As a final note, many authors indicate that the research studies in elementary science education suffer from major inadequacies. Haney et al. pointed to four weaknesses in the studies they examined for the years 1965-1967: lack of precise terminology, poorly defined variables, brief treatment periods on unrepresentative groups, and inadequate instruction (in Gallagher, 1972). In a summary of research in science education during 1968-1969 (elementary level), Gallagher (1972) found many of the weaknesses identified by Haney and his colleagues to be still observable. In addition, Gallagher states that the quality of reporting is usually poor and faulty experimental design was common.

In light of the various challenges that have yet to be met in science education, Tyler (1968) cautions against an uncritical acceptance of the new science curricula. Programs should be carefully analyzed in terms of goals, attitudes, processes and products as they relate to the society in which children have to live.

Need for a Philosophical and Theoretical Perspective in Science Education

Despite the interest, time, effort, and money that have been expended in improving science education, the heart of the problem remains unaddressed. A survey of the literature indicates that this is a critical juncture in the history of science teaching. This is summed up by Pella's (1966) comment that science education has been floundering for many years because individuals are concerned with make-shift remedies rather than trying to reach the source of the problem. In fact, it is somewhat paradoxical that scientists have not brought the methods of science to bear on the improvement of science instruction (Skinner, 1968).

Other eminent science educators echo the same sentiments. Paul DeHart Hurd, a leading educator in the field, addresses the challenge with insight and indicates the urgent need for a theoretical framework in science education.

> Not to establish a theoretical position means that we continue to attack educational problems on a haphazard basis, always pot-shotting, and fragmenting our efforts rather than making a broad attack on the frontier of the unknown. (1971:244)

Because the tendency is to operate on an atheoretical basis, every investigation is a separate problem. Without an underpinning of theory, many research findings are lost "in a fog of contradictions" (Hurd, 1971:244) and have no impact on the educational process. Research results do not reach the classroom teacher and the experiences and accumulated insights of the teacher are never heard by the investigator. The rich and rewarding interplay between theory and practice is left untapped.

The reason proposed by St. John for the lack of a viable theory in science education is that whatever form of theoretical framework that exists (if indeed it does) is based upon common sense. These frames of reference vary with each investigator or with each new curriculum that is developed. A viable theory which is based on synthesis of the research findings of human growth and development should be able to offer direction, leadership, power, and economy to the field and provide a basis for decision making (St. John, 1966).

The function of a theory is to make simple the complex and bring order to confusion. Education has been dependent upon the social sciences for so long that it has ignored the formulation of any theoretical framework. Pella (1966) identifies some of the factors that need to be considered in developing a workable theoretical base for science education, namely, philosophy, the nature of learning, the nature of knowledge, and the nature of the curriculum.

In the area of early childhood education Howe (1975) has proposed a theoretical basis for science activities. Her thesis is that pre-school teachers do not have a rational basis for making decisions as to what science experiences are appropriate for the very young child. Howe proposed Piaget's theory of the stages of intellectual development as a possible base from which teachers can operate. Certainly knowledge of development is an invaluable guide in teaching, but an effective theoretical scheme has to be more comprehensive and address other issues rather than just cognitive growth. However, Howe's proposal has merit in that it is one of the few articles that confronts the issue of formulating a theoretical scheme. Bowen (1975) offers Ausubel's learning model as a conceptual framework that can guide science education research.

Not only is a theoretical framework necessary in science education but the necessity of an underlying philosophical perspective is also emphasized by various authors. Showalter (1975) states that a philosphic rationale that can reflect the unity of the sciences will be useful. Raven (1970), in an article on a philosophical basis for selecting science curriculum content, leans towards Margenau's metaphysical requirements of how scientific knowledge is gained. As a most insightful science educator, Hurd states that "We can contribute to the improvement of our field (i.e., science education) by exposing our educational theories to philosophic criticism" (1971:244).

The power of a philosophical perspective is eloquently described by Whitehead. He suggests that a philosophy not only molds the life of the individual but it also influences our type of society and even our civilization. He claims that

> Philosophy is the attempt to make manifest the fundamental evidence as to the nature of things. Upon the presupposition of this evidence, all understanding rests . . . It makes the content of the human mind manageable; it adds meaning to fragmentary details; it discloses disjunctions and conjunctions, consistencies and inconsistencies. (1968b:48-49)

The position that I am setting forth and justifying in this dissertation is that the fragmentation in science education cannot be dealt with unless educational theory and practice as a whole are guided by general philosophical principles. For science education, as the particular focus, the philosophical scheme of thought should be compatible with the advances in contemporary scientific thought.

In the next chapter, two broad streams of philosophical thought, namely, mechanistic and organismic, will be examined for the purpose of discerning which scheme would be of most value to science education. I submit that the kind of philosophical perspective that would be most useful is one which includes an understanding of the nature of man, the essence of physical reality, and how these two concerns are related.

CHAPTER II

TOWARD A SHIFT IN THE PARADIGM OF CONTEMPORARY SCIENTIFIC THOUGHT

A survey of the Western philosophical tradition indicates the existence of two major antithetical systems of thought; namely, the mechanistic system and the organismic system (Montalenti, 1974). For centuries, the proponents of these two schemes were opposed to each other. Now, in the twentieth century, there appears to be a gradual acceptance of some of the fundamental principles of the philosophy of organism by adherents of the mechanistic tradition. Essentially, the change is occurring in the contemporary scientific conception of the nature of man, the nature of the physical universe and the nature of life.

In the language of Thomas Kuhn, this change in our world view constitutes a "paradigm shift" (1970). A paradigm may be defined as a shared scheme of thought from which arise certain scientific traditions. For example, it is common to read about "Ptolemaic astronomy" or "Newtonian mechanics." The prevailing tradition or paradigm is always accepted as the most workable system in relation to our understanding of particular phenomena. In time, anomalies or unexplainable events are recognized. This casts doubt on the established paradigm. At this point, a new scheme of thought is proposed. If the new scheme or paradigm not only accounts for the anomalies but also includes ideas that worked in the past, then people will eventually rally behind it and a "shift" occurs. For example, this kind of a shift in paradigm occurred when Einstein's theory of relativity superceded the older Newtonian views of absolute space and time. The change in our mental conception of the universe as a result of this paradigm shift has been fundamental--physical events, life, people and feelings are all viewed as being relative rather than fixed and absolute.

Roots of the Mechanistic and Organismic Systems of Thought

The roots of the mechanism versus organism controversy date back to the philosophical thought of the early Greeks (Montalenti, 1974; Smith, 1976). Atomism or mechanism is most clearly associated with the Greek philosopher Democritus. He held the view that the phenomenal world was composed of an infinite number of small, invisible particles which came together and then fell apart purely by chance and at random.

Aristotle vehemently challenged the Democritean position on the fortuitous nature of existence. Instead, he proposed a teleological theory, which stated that events in nature do not happen at random but do so with an end in view. The word teleological is derived from the root "teleos" which in Greek means end, complete or perfect. So, for Aristotle, the end state was one of the most important reasons for the occurrence of any event. He included this notion of the end state in the "doctrine of the four causes." The concept of "cause" was used in a much broader and general way than it is used today. The four causes may be defined as follows:

(a) Material cause is that from which something is created;

(b) Formal cause is the form, design of pattern of a thing;

(c) Efficient cause is the action which effects some change from the original state, and

(d) Final cause is the reason why things happen (i.e., the end or purpose).

The introduction of the final cause or internal purpose represented a more organismic conception of the universe. That is, efficient causes cannot account solely for why events occur in the world. A philosophy of mechanism, however, holds that all physical events can be explained solely in terms of efficient causation and denies the operation of any internal purpose or final cause. The rise of the physical sciences in the seventeenth century was characterized by the mechanistic views of Newton and strict empiricism.

Today, in the latter half of the 20th century, there is a pressing and critical urgency to move beyond atomism and mechanism while still retaining the advantages of a successful mechanistic methodology. Scientists are becoming aware of the need for integrative and holistic approaches to understanding man and the universe. Issues such as fulfillment, consciousness, purpose or goal-directedness, organization, systems, hierarchy and emergence have been, and will continue to be, discussed and debated by scientists and philosophers of science (Koestler and Smythies, 1969; Ayala and Dobzhansky, 1974). A new world view or a new paradigm is needed to account for the notions mentioned above. Ultimately, any new successful paradigm that is formulated by scientists has relevance for the educator who has to distill and synthesize the accumulated knowledge into a coherent and effective educational system.

In trying to discern the shift from extreme mechanism to even moderate organismic views, I will concentrate on the major issues that appear to be of greatest concern to scientists. For the sake of clarity, the issues may be grouped into three broad categories, namely

(1) the organization of systems

(2) hierarchical structuration and integration

(3) efficient and final causation.

To show the impact of these concerns upon contemporary scientific thought, the discussion will be placed in a broader context and include the physical, life and social sciences.

Organismic Principles in Contemporary Scientific Thought

Organization of Systems

The rise of the organismic or systemic view of nature heralded the age of synthesis and integration. Ortega y Gasset, with great insight, says

> The need to create sound syntheses and systematizations of knowledge . . . will call out a kind of . . . genius which hitherto has existed only as an aberration; the genius for integration. Of necessity this means specialization, as all creative effort inevitably does; but this time man will be specializing in the construction of the whole. (in Laszlo, 1973:35).

Holistic understandings of the world are by no means new. Two millennia ago, the famous symbol of the "Ouroboros" (the snake eating its tail) was well known in ancient China and in Alexandria. It expresses the notion of "the one, the all" which implies "that one entity incorporates into itself in some sense all other entities in the universe" (Waddington, 1975:2-3). Five hundred years ago, the German philosopher Nikolaus von Kues said, "ex omnibus partibus relucet totum," that "from every part, the whole shines forth" (Donath, 1973:117). This idea remains valid even today when all the part-whole phenomena prove the material unity of the universe.

In trying to understand the organization of systems it is first necessary to define the concept, "organization." The concept of organization is of crucial importance in the sciences. Bertalanffy (1968a) states that organization was not considered as an integral aspect of a mechanistic world in which isolated events were investigated. In fact, the 2nd principle of thermodynamics discussed the destruction of order, but contained no corresponding principles for the establishment of order and organization. Bertalanffy goes on to point out that Whitehead never failed to emphasize that "an atom, a crystal, or a molecule are organizations. In biology, organisms are, by definition, organized things" (Bertalanffy, 1968a:47). It was Bertalanffy, who in the late 1920s originated the phrase, "organismic biology," to indicate the necessity of regarding the living organism as an organized system.

Sinnott, in discussing the problem of organization from a biologist's point of view, makes reference to Whitehead's philosophy of organism. He says that

> Our problem, though first the task of the biologist, must evidently transcend his domain and enter that of philosophy. The list of philosophers who have undertaken to deal with it is considerable. Most notable among them, perhaps, is Whitehead, who based an important part of his system upon the fact of organization, not only in living things but throughout the universe. Biology for him is the study of the larger organisms and physics that of the smaller ones. The notion of particle he would replace by the notion or organism. (1950:42)

In Whitehead's cosmological scheme, organisms are viewed as actual entities which are the final real things of our perceptions and conceptual understanding. The organization of these actual entities is governed by various principles such as the principles of process and relativity. An organism's becoming or actualization is exemplified in the process of change from one thing to another; at the same time the becoming of one organism is related to the becoming of every other organism in some way, such that ". . . every item in its universe is involved in each concrescence" (Whitehead, 1969:27). Concrescence as used here means literally the growing together of a unity of experience. Further on, he says that

> Thus the ultimate metaphysical truth is atomism. The creatures are atomis . . . But atomism does not exclude complexity and universal relativity. Each atom is a system of all things. (1969:41)

It has to be understood that Whitehead's terminology does not carry the usual meanings that we attribute to certain words. In the quote above, "atomism" reflects the root meaning of the word, "unsplittable," and means that each organism can only be understood as a whole which is more than the sum of all its parts. Organization, then, for Whitehead is synonymous with interrelatedness or a universe of relations.

The notion of "systems" as a complete set of elements with mutual interrelations (Blauberg et al., 1973) has gained widespread influence in the physical, life and social sciences. General systems theory was initiated and developed by Ludwig von Bertalanffy in response to the fragmentation and over-specialization of knowledge. Bertalanffy defines general system theory as

> . . . the scientific exploration of "wholes" and "wholeness" which, not so long ago, were considered metaphysical notions transcending the boundaries of science. Hierarchic structure, stability, teleology, differentiation, approach to and maintenance of steady states, goal-directedness--these are a few of such general system properties . . . (in Laszlo, 1973:xviii)

General system theory was developed as an interdisciplinary approach toward the unification of science but the achievement of this goal remains yet to be seen. A fruitful line of enquiry blossomed into what may be called computerized investigations such as systems analysis, systems engineering, cybernetics, information theory, etc., which are based on mechanistic notions. The concern in this dissertation is with those aspects of system theory which may be identified as "systemic," i.e., the relationship between parts and wholes, mutual interconnections, goal-directedness, etc. Laszlo clarifies the systemic aspect of systems theory when he writes that

> . . . to have an adequate grasp of reality we must look at things as systems, with properties and structures of their own. Systems of various kinds can then be compared, their relationships within still larger systems defined, and a general context established. . . . the system view always treats systems as integrated wholes of their subsidiary components and never as the mechanistic aggregate of parts in isolable causal relations. (1972:14-15)

System properties, which are in essence similar to the basic propositions of an organismic philosophy, present a view of the universe as unified diversity. The ancient Ouroboros and the modern holon (after Koestler, 1969) are indicative of the necessity of seeing an entity as a whole in its own environment and a part in the totality. The oft-quoted phrase "the whole is more than the sum of its parts" becomes a reality when the collective behavior of the parts is considered in an organized group. As Weiss says

> . . . carrying out this upgrading process . . . is in effect . . . no more than <u>restoring information content</u> that has been lost on the way down in the progressive analysis of the unitary universe into abstracted elements. (1969:11).

In the realm of the physical sciences, modern atomic physics has already made a departure from a strictly mechanistic and particulate view of the physical world. One of the most remarkable principles of atomic physics was formulated by Wolfgang Pauli in 1925 and was called the Exclusion Principle. Simply stated, the Pauli Exclusion Principle rules that no two electrons can occupy the same position at the same time. Therefore, the excluded electron moves beyond to occupy the next empty shell. Margenau, in writing about the singular status of this principle, says that "the peculiar integrative significance of the exclusion principle passed from view and has even now been rarely recognized in its philosophical fullness" (1972:63).

The philosophical significance is well-stated by Margenau:

> Prior to that time (before the exclusion principle) all theories had affected the individual nature of the so-called "parts"; the new principle regulated their social behavior. With respect to a single particle it has nothing to say. And what it says for aggregates, though most important, cannot be expressed in terms of dynamic regulation. It is as though here, for the first time, physics had discovered within its own precincts a purely social law, a law that is simple in its basic formulation and yet immense in its collective effects. Mechanistic reasoning, already far behind, has gone out of sight as a result of this latest advance. (1950:442-3)

Thus, the tendency of two electrons to avoid each other was of extraordinary importance and provided explanations for phenomena that give rise to the ordered sequences and arrangements in physical objects. Such apparently "co-operative" effects in inorganic matter accounts for such phenomena as atomic structure, chemical binding, crystal shape, cohesion of solids, magnetism, electricity, etc. Margenau (1972) thus calls the exclusion principle a "postulate of symmetry." From a systemic or organismic perspective, this principle becomes meaningful because it has no relevance for single electrons but only at the level of the interrelations among electrons in a collective.

Similarly, in biology, living organisms display phenomena that may be called "group behavior" (Weiss, 1969). It is only by virtue of "ordered interactions (that) . . .

molecules become partners in the living process" (Weiss, 1969:8). A description of the parts of the living organism do not account for the emergence of higher principles in the whole. Bertalanffy's "organismic biology" of the 1920s is certainly applicable in modern biology today.

Weiss, in discussing living systems, states that there is still a tendency amongst biologists to think that given time and through the consistent application of the analytic method and then the synthetic mode, will come to an understanding of the phenomenon of life. This view, he says, is not adequate.

> We are concerned with <u>living organisms</u>, and for those, we can assert definitely, on the basis of empirical investigation, that the mere reversal of our prior analytic dissection of the Universe by <u>putting the pieces together</u> again, whether in reality or just in our minds, <u>can yield no complete explanation of the behavior of even the most elementary living system</u>. (1969:7)

An organismic perspective is concerned with the unique characteristics of the whole as a system, as well as the relationship between the parts that constitute the unified entity. As important as analytic investigations are, synthesis and integration are just as vital to give us a complete picture of the nature of reality.

Hierarchical Structuration and Integration

Lancelot Law Whyte, an eminent proponent of the hierarchical nature of systems, traces the historical roots of the term "hierarchy" to the time of the Greeks. "Hierarchy" is derived from the Greek "hiero," holy, and "arkhia," to rule. According to Whyte, the earliest or archaic meaning in Greek for "hiero" was "vigorous" or "energetic," such that "hierarchy" could have meant "energetic control." This meaning is remarkably similar to our present day understanding of the hierarchical character of systems.

The concept of hierarchy may be defined generally as "a set of things graded in levels by asymmetrical relations" (Whyte, 1973:275) or ". . . each integration level implies the appearance of new qualities, new relationships, which impose the need of new criteria of explanation" (Montalenti, 1974:13). Both these definitions relate the notion of hierarchy to concepts of systems, wholeness, order and interrelatedness.

Weiss (1969) points out that the mere mention of the term "levels" is a fundamental distinction between the mechanistic and holistic means of explaining phenomena. From a mechanistic point of view, all phenomena are reduced to ultimate particles and whatever relationship exists among them is seen as a set of continuous gradations from the single elements to infinite combinations of them. The hierarchical nature of existence seems to imply some sort of boundary condition as the transition is made from a lower to a higher level (Polanyi, 1967, 1976). However, empirical study reveals that all existence is hierarchically organized and that more complex levels exemplify higher principles of operation. Weiss states that even though different levels exist, it is the organization of these levels in a "dynamic" wholeness that was the sensitive point. He says

> . . . the systems concept is the embodiment of the experience that there are patterned processes which owe their typical configuration not to a prearranged, absolutely stereotyped mosaic of single-tracked component performances, but on the contrary, to the fact that the component activities have many degrees of freedom, but submit to the ordering restraints exerted upon them by the integral activity of the "whole" in its patterned systems dynamics. (1969:9).

Many hierarchical classifications of the physical world have been postulated, most notably by Whitehead (1969), Laszlo (1973), Whyte (1973), and many others. The most frequently cited are those hierarchies which begin with inorganic nature, that is, from elementary particles to atomic nuclei, atoms, molecules, cells, organisms, ecosystems and a world system. Whitehead's scheme is radically different in that he begins with human existence and works his way in reverse direction to the ultimate happenings in atoms. This view is not in conflict with the part/whole relationships and the hierarchical order of nature except that in this scheme Whitehead is able to explain the emergence of consciousness, purpose and intentionality more adequately.

The problem of accounting for the phenomenon of hierarchical order has been largely the challenge of the life sciences (in particular, biology) in the form of reductionism. Barbour's definition of reductionism makes clear why this is a problem especially if it is seen as

> the attributing of reality exclusively to the smallest constituents of the world, and the tendency to interpret higher levels of organization in terms of lower levels. (in Thorpe, 1974:110)

Elementary phenomena in biology can be reduced to physical and chemical explanation and this is always fully valid and in fact necessary, as far as it goes, but if these explanations are used to account for integrations above the molecular level, then they are no longer adequate or sufficient. The enormous advances and successes in molecular biology, genetics, and medicine would not have been possible without the detailed analytic, reductionist approach. Ayala (1974), in the Preface to <u>Studies in the Philosophy of Biology</u>, analyzes the kinds of reductionism that a scientist may espouse or reject. He identifies three types: (1) ontological reductionism, which reduces all living phenomena to physical chemical processes and particles; (2) methodological reductionism, which is concerned with the strategy of research, e.g., should lower levels be studied first to explain the higher or should both higher and lower levels be investigated?; and (3) epistemological reductionistic questions that ask whether "the theories and experiential laws formulated in one field of science can be shown to be special cases of theories and laws formulated in some other branch of science?" (Ayala, 1974:ix). Most biologists can accept methodological reductionism but differ in their acceptance of the other two forms.

If the methodology is so successful, then, as Thorpe (1974) maintains, it is necessary to look very carefully into those specific areas in which it does fail. It appears that reductionism cannot explain the concept of "emergence." Broad's definition of "emergence" is clear and illuminating.

> Emergence is the theory that the characteristic behavior of the whole could not, even in theory, be deduced from the most complete knowledge of the behavior of its components, taken separately or in other combinations, and of their proportions and arrangements in this whole. (in Thorpe, 1974:110)

For example, the emergence of life in a cell cannot be explained by simply putting together various combinations of molecules. In the field of animal behavior, concepts such as memory, habituation, learning, peripheral synthesis, etc., emerge which do not exist at the vegetable level. Similarly, at the level of human existence, the unique capacity of consciousness, purposiveness, values, moral intentions and religious convictions make their appearance. It is indeed not possible to reduce these emergent qualities solely to the operation of physical and chemical processes even though without the material at the level of atomic and elementary particles, these qualities would not emerge.

Even in the realm of atomic physics Margenau (1972) identifies the emergence of more important laws at higher levels of complexity. He states that it is possible to describe the state of a small system of particles in terms of position, velocity and forces as in Newtonian mechanics. However, at the next level of aggregates such as a gas or liquid it is useless to describe position, velocity and force in terms of individual molecules. Concepts such as temperature, pressure, entropy, etc. are now necessary--in relation to single molecules these concepts have no meaning. However, it is possible to infer through statistical mechanics the collective properties of a gas if the positions and velocities of individual molecules are known. The reverse, however, is not true. Margenau says

> . . . that there is continuity of explanation from below, but not from above. One can go continually toward an understanding of matters on the higher plane if one starts with knowledge on the lower plane, though not in the reverse direction. But in this ascent, knowledge on the lower plane becomes irrelevant because new concepts like temperature, etc., emerge and these have no direct reference to particles. (1972:42)

Similarly, the behavior of individual elementary particles is explained by the Schroedinger equation which in a way is similar to Newton's 2nd law as it relates to force, mass and motion. If several elementary particles of the same kind are present, then the more important Pauli

Exclusion Principle operates.

In writing about social hierarchies, Arthur Koestler presents an interesting analysis of the individual as a part, and of society as a whole.

> The single individual constitutes the apex of the organismic hierarchy, and at the same time the lowest unit of the social hierarchy. Looking inward, he sees himself as a self-contained, unique whole; looking outward as a dependent whole. . . . His self-assertive tendency is the dynamic manifestation of his unique wholeness as an individual; his integrative tendency expresses his dependence on the larger whole to which he belongs, his partness. (1969:302)

Koestler states that the self-assertive tendency is associated with the biological concerns of survival at the level of the individual. The emotions that are triggered through this tendency are defense and aggression, hunger, fear and rage. Integrative tendencies give rise to what may be called "self-transcending or participatory" emotions such as the human being's need to be part of a larger whole, e.g., social groups, bonds and ties of affection, belief and value systems. The individual functions as an autonomous being but at the same time is a part of, but different from, the larger reality or nation.

An organismic perspective is concerned with patterns of organization that are reflected at different integrative levels. A particular pattern of relations as exemplified in a whole is unique to that whole and cannot be reduced to the pattern of the part.

Efficient and Final Causation

> A satisfactory cosmology must explain the interweaving of efficient and final causation . . . The two spheres of operation should be interwoven and required, each by the other. But neither sphere should arbitrarily limit the scope of the alternative mode. (Whitehead, 1958:28)

An organismic perspective, if it is to remain faithful to its principles of wholeness and interrelatedness, must acknowledge the operation of both efficient and final causes. Emphasis on one to the exclusion of the other leads to contradiction. The rejection of final cause dates back to the 17th century and the rise of modern science. The inevitable outcome of the early empiricist scientific philosophy led to the belief that

> Nature is a dull affair, soundless, scentless, colorless, merely the hurrying of material endlessly, meaninglessly. (Whitehead, 1967:54)

It was this kind of a perspective that propelled the French astronomer and mathematician Pierre Laplace, in the mid-17th century, to formulate a principle which today is called the "Laplacian Illusion." He stated that if one knew the exact position and motion of every atom then the entire future of the world could be predicted. Causality in this narrow sense is called determinism by which is meant "that there are immutable laws that uniquely determine the future state of any system from its present state" (Heisenberg, 1970:34).

Even though such strict deterministic and mechanistic views are not adhered to so vehemently by scientists of today, the notion of final cause or teleology, is not readily affirmed. Criticism of the use of teleological concepts is traditionally based on several objections. Mayr, a strong opponent on this score, outlines the major objections as being (1) teleological explanations impart an unverifiable metaphysical or theological doctrine into science; (2) the assumption that a pre-conceived future goal was the cause of current events is contrary to the concept of causality; and (3) teleological language seems to involve "objectionable anthropomorphism" (1974:93-94).

To overcome these objections in living organisms which do display goal-seeking as intrinsic phenomena, the term "teleonomy" was coined by Pittendrigh (in Mayr, 1974). His reasoning went along these lines:

> What it was that the biologist could not escape was the plain fact--or rather the fundamental fact--which he must (as scientist) explain: that the objects of biological analysis are organizations (he calls them organisms) and as such, are end-directed. Organization is more than mere order; order lacks end-directedness, organization _is_ end-directed. (Pittendrigh in a letter to Mayr, 1974:115).

Pittendrigh's intention was to describe the end-directedness of a mechanistic system, the only kind of system that was acceptable to scientists. Mayr presents a modified definition of teleonomy which is still strictly causal and mechanistic:

> A teleonomic process or behavior is one which owes its goal-directedness to the operation of a program. (1974:98)

This definition refers only to living organisms and man-made machines, in which a program may be the DNA code or a computer program, respectively.

At the level of evolutionary biology where scientists are dealing with crucial issues such as the origin of life and the emergence of man, the tendency to maintain only an efficient causal explanation is still evident. Waddington cites Mayr's views on 20th century Darwinism in the following two postulates:

> (1) that all the events that lead to the production of new genotypes, such as mutation, recombination and fertilization, are essentially random and not in any way whatsoever finalistic, and
>
> (2) that the order in the organic world, manifested in the numerous adaptations of organisms to the physical and biotic environments is due to the ordering effect of natural selection. (Waddington, 1962:85)

From these postulates, the neo-Darwinists hold that "natural selection is an ordering process which brings design out of randomness" (Birch, 1974:227) and this is logically indisputable. For Dobzhansky "Evolution is 'nomogenesis' . . . Its 'law,' nomos, is natural selection" (Dobzhansky, 1974:312). He goes further and attributes creativity and the rise of the diversity of organic forms to natural selection alone. Mayr (1961) also subscribes to the view that natural selection is the sole instrument of evolution.

The crucial question is identified by Birch (1974) when he asks whether natural selection is the one and only ordering process in organic and biological evolution. Montalenti (1974), a neo-Darwinist who acknowledges the omnipotence of natural selection, refers to the above sentiments as "unresolved questions." The rise of phenomena such as consciousness and purpose in man do not receive adequate explanations from the process of natural selection.

It appears that other factors have to be included if goal-directedness, consciousness and intentions are to be accounted for. Waddington notes that

> We have considerable grounds for believing then, that mentality in the broad sense, or at least behavior (biologists tend to be very timid about mentioning the mind), is a factor of importance in evolution . . . The situation is that existing modes of behavior [themselves controlled, with greater or lesser latitude, by heredity] combine with the external circumstances to determine the nature of the effective environment. (1962:91)

He expands on the notion of "mentality" in what he calls a four-factor theory of evolution comprised of "the genetic system, the natural selective system, the exploitative system, and the developmental or epigenetic system" (Waddington, 1975:270). The exploitative system is the area in which the organism or entity has some "internal determination" in interacting with the environment. Waddington (1962) cites the example of letting loose a hare and a rabbit in an open grassland. Instinctively, the hare makes its home in the open field and the rabbit in the hedge or a bank. However, it is not possible to predict exactly where in the field or which actual site in the hedge will be chosen. For Waddington, having been deeply influenced by Whitehead, it is the interaction between the internal state of the organism and the external pressures of the environment that constitute the epigenetic principle reflected in the shift to organismic thinking in evolution (Waddington, 1962).

Internal determination is one of the main propositions of the Whiteheadian organismic thesis. Whitehead terms it the "subjectivist principle," that everything is in part determined by its own internal state. This does not imply that there is no external agency, such as the environment, that influences this state. But the environment does not fully determine the behavior of any given entity. In man, the ability to determine the future course of his evolution is unbounded. Consciousness and the capacity for symbolization allow man to store information in his memory, make plans for the future, and so affect what he will become. The subjectivist principle in man is translated into subjective aim or purpose or intentionality. If man is viewed as an integral part of nature, having evolved from other forms, then that which is inherent in man must also exist <u>in some form</u> in other levels of existence. Whitehead says

> Mankind has gradually developed from the lowliest forms of life, and it must therefore be explained in terms applicable to all such forms. But why construe the later forms by analogy to the earlier forms? Why not reverse the process? It would seem to be more sensible, more truly empirical, to allow each living species to make its own contribution to the demonstration of factors inherent in living things. (1958:15)

The contribution of existence at the mineral, vegetable and animal levels is that some internal determination exists in what they become, but not as consciousness, purpose or aspirations which are unique to man. A stone has very little determination over what it becomes, but even so its atoms have some determination over where they finally reside. Similarly, in the plant and animal spheres, some internal state is operative, in a small way in plants, but much more evident in animals. The subjectivist principle is Whitehead's equivalent of final cause in evolution; randomness and chance are characteristic of events which are not completely determined by some external agency.

In his major work, Process and Reality, Whitehead accords the notion of efficient and final causation a particular status in his categorical scheme. He claims

> That every condition to which the process of becoming conforms in any particular instance, has its reason either in the character of some actual entity in the actual world of that concrescence, or in the character of the subject which is in the process of concrescence. This category of explanation is termed the "ontological principle." It could also be termed the "principle of efficient, and final, causation." (1969:29)

The efficient cause in the evolutionary process is natural selection, which acts upon the organisms that already exist in the physical world. Final cause is a factor in the character of the subject or the internal "urge" or determination towards self-completion in the process of becoming.

Charles Birch (1974), in an essay on "Chance, Necessity and Purpose" in evolution, examines the issue of teleology from a Whiteheadian perspective. He cites the views of Thomas Huxley on evolution and teleology.

> The doctrine of evolution is the most formidable opponent of all the commoner and coarser forms of Teleology . . . Nevertheless, it is necessary to remember that there is a wider teleology which is not touched by the doctrine of Evolution, but is actually based upon the fundamental proposition of Evolution. The proposition is that the whole world, living and non-living, is the result of mutual interaction, according to definite laws, of the powers possessed by the molecules of which the primitive nebulosity of the universe was composed. If this be true, it is no less certain that the existing world lay potentially in the cosmic vapor . . . The teleological and the mechanical views of nature are not, necessarily, mutually exclusive. (Huxley, in Birch, 1974:228)

The key phrase, "the existing world lay potentially in the cosmic vapor" can be interpreted in terms of Whitehead's organismic philosophy, which elaborates upon the process of translating potentiality into actuality. All the determinate actual entities in the world of existence did not arise out of nothing--the potential for actualization existed. Something does not come from nothing, but from something, and for Whitehead this something is the realm of potentiality or possibility, which has the capacity for actualization in some future state.

Birch explains the notion of potentiality in evolution as follows:

> We tend to take for granted the potentialities nascent in the unevolved cosmos from its foundations and without which the emergence of life and consciousness would not have been possible. Potentialities are unseen realities. In Huxley's statement is the idea of the potentiality of the phenomena of the universe residing in the primordial particles. Far from being a preformist view this is an epigenetic view of nature. There is no necessity that what is potentially possible must eventuate. What eventuates depends upon chance and circumstance. (1975:228)

The philosophy of organism as set forth by Whitehead is comprehensive enough to account for not only final cause as internal determination and the potential for realization, but also for natural selection as the efficient cause in the process of evolution.

In the field of atomic physics, the Pauli Exclusion Principle and Heisenberg's Uncertainty Principle are in essence measures of the internal determination in a system. Heisenberg, in discussing the statistical nature of quantum theory, says

> . . . that quantum theory actually forces us to formulate these laws precisely as statistical laws and to depart radically from determinism. (1970:39)

He continues:

> . . . incomplete knowledge of a system must be an essential part of every formulation in quantum theory. (1970:41)

The very act of trying to measure the position and velocity of an atomic particle obscures the required data. Under these conditions the particle "behaves" differently.

Heisenberg provides examples of some of these uncertainty relations in quantum theory. In discussing the alpha-radiation of a radium atom, he says that quantum theory, through statistical laws, can give some information of the probability of an alpha particle leaving the nucleus

> . . . but it cannot predict at what precise point in time emission will occur, for this is uncertain in principle. We cannot even assume that new laws still to be discovered will allow us to determine this precise point in time . . . (1970:41)

Similarly, in calculating the strength of an atomic bomb, only the upper and lower limits of the magnitude of explosion can be predicted. Exact calculations are impossible because it depends on the behavior of only a few atoms when the detonation occurs. The particular atoms which will take part in the fission cannot be predicted precisely. That is, the atoms which actually participate in the process must somehow be determined internally in the system. In Whiteheadian terms this is the subjectivist principle in operation, that is, the final cause or "purpose" is to some extent determined by internal relations in the collective system of atoms.

Even in the social sciences, ever since the divergence of psychology from philosophy, man has been conceived of in mechanistic terms or just efficient causes. The significant event was the publication of Newton's Principia which set forth the major principles of classical mechanics. The prevailing idea was that the behavior of man could be explained in terms of Newton's mechanical model. Science viewed man in terms of input and output and cause and effect explanations of behavior which created the vision of a robot or a puppet. Michael Polanyi (1974) discusses this notion in a thoughtful manner, having first been a scientist and then turning to philosophy to disclose the nature of the scientist's thought, his beliefs and convictions, and his influence upon society. He says, "A complete causal interpretation of man and human affairs disintegrates all rational grounds for men's convictions and actions. It leaves you with a picture of human affairs construed in terms of appetites and checked only by fear" (Polanyi, 1974: 64).

This view was widely held by experimental psychologists in the early 1900s in the established behaviorist tradition. Psychological thought processes were explained by efficient causes, i.e., cause and effect relationships. The notion of man as being guided by final cause, i.e., the ingression of purpose and will in his life was ruled out as unscientific. Any evidence that lay outside the successful methodology was ignored. Scientists spend years of their lives patiently designing experiments for the purpose of proving that animals are only motivated by psychological drives and needs. Whitehead's comment is apt: "Scientists animated by the purpose of proving that they are purposeless constitute an interesting subject for study" (Whitehead, 1958:16).

Purpose is the driving force in man; it gives direction, guidance and power in the pursuit of a successful and meaningful life. Society is plagued with individuals who are on the verge of absolute despair or who display crass hedonism because of a purposeless existence. Towers (1971), in citing Frankl's notion of the "existential vacuum," states that the insignificance of man has been caused by (1) astronomy, which is the science of the infinitely large; (2) the uncertainty principle, which robs us of any belief in certainty and stability; and (3) psychotherapy, which analyzes and reduces praiseworthy human actions to nothing but inner, unconscious, unresolved drives and conflicts. The result has been the overwhelming spirit of "being adrift in a totally meaningless universe." Frankl says that

> We may define the existential vacuum as the frustration of what we may consider to be the most basic motivational force in man, the will to meaning. . . . It is an inherent tendency in man to reach out for meaning to fulfill, for values to actualize. (1969:398-400)

However, the rise of humanistic psychology and organismic philosophy have presented the necessity of viewing man as a being who is purposeful, forms goals, makes choices, and who is endeavoring to become his unique, individual self (Rogers, 1964).

Just focusing on efficient causes either in nature or in man presents only a limited view of reality. An organismic perspective in adhering to the principle of relatedness seeks to reunite both the external and internal aspects of events in nature and in human experience. Efficient and final causation reflect the patterned unity that is necessary if we are to have any meaningful understanding of reality.

Toward an Organismic Perspective in Science Education

The preceding discussion on the organization of systems, hierarchical structuration and integration, and efficient and final causation was undertaken so that the organismic perspective in scientific thought could be made more explicit. Certainly not all scientists would subscribe to such a viewpoint. However, in trying to ascertain where contemporary scientific thought stands, one necessarily focuses on the work of those who are at the forefront of knowledge, those prominent figures who see the growth of our understanding about reality in an evolutionary perspective. These are the scientists who effect revolutions in our accustomed and comfortable ways of thinking, who capture visions of the future, and who seek to interpret the totality of reality. The new patterns of thinking in science, imperceptible as they may seem, pervade our consciousness and have the power, as Whitehead claims, "to recolor our mentality." Anshen, in the Preface to the World Perspective series, clearly describes the impact of the scientific view of reality:

> For our problem is to discover a principle of differentiation and yet relationship lucid enough to justify and to purify scientific, philosophic and all other knowledge, both discursive and intuitive, by accepting their interdependence. This is the crisis in consciousness made articulate through the crisis in science. This is the new awakening. (1971:xi)

The point of view adopted in this dissertation is that an organismic philosophy can accommodate the merits of mechanism but can also transcend its limitations with an emphasis on wholeness, unity and organism and so provide a comprehensive view of the nature of man and the nature of physical reality. Whitehead's process philosophy or philosophy of organism was found to be the most expansive, particularly in the range of issues which it could address.

The organismic philosophy advanced by Whitehead views the universe as being characterized by change and dynamic interactions rather than static actuality. Change implies process which automatically presupposes potentiality. Potentiality becoming actuality is the central thesis of a philosophy of organism. Any active, developing, open system, rather than maintaining a steady state, can be seen to exhibit the powerful processes of change, growth and adaptation. At every moment these dynamic systems are in the process of actualizing a potential state of being. Whitehead states that "the actual world is a process, and that the process is the becoming of actual entities" (1969:27).

Man, as a flexible and active system, is also an integral part of this hierarchically structured universe. He may be viewed as being in a continuous, dynamic process of development and transformation with the capacity to perpetually actualize his potentialities and fulfill his intentions and aspirations. The perpetual actualization of potentiality is manifested in the tremendous strides that man has made in the fields of science, medicine, and technology, such that he has the power to constantly improve the quality of his life, if these powers are used wisely. Maintenance of a high quality of life is conditioned by the continuous translation of potentiality into actuality at an optimal rate. Whitehead (1958) postulates the facilitation of actualization of potential as the primary purpose of life, since the aim of survival is not only to live but to be alive in a more satisfactory manner.

I propose that science education should appeal to the central proposition of the philosophy of organism: that the reality of all of creation on every level is to be found in the process of becoming and that man must be accepted as a purposeful being who has the power to actualize his potential and contribute to the collective survival of mankind. Science curriculum development then, in its broadest sense, will have to focus not only on fostering the growth of understanding of scientific concepts, but also on how that knowledge is to be applied.

The following chapter sets forth a possible approach to solving some of the problems raised in Chapter I. The Anisa Model is presented as one viable scheme that incorporates an explicit philosophical base (derived from the work of Alfred North Whitehead), and a coherent theoretical framework that can address the issue of science curriculum development in a wider context.

CHAPTER III

THE ANISA MODEL: AN INTEGRATIVE SYSTEM FOR UNDERSTANDING THE ROLE OF SCIENCE IN THE ACTUALIZATION OF HUMAN POTENTIAL

The abstract, general principles of a philosophical scheme of thought do not directly issue in action. These principles need to be translated into a coherent theoretical framework that can guide practice. Jordan & Shephard, in describing the role of philosophy, say that

> A more specific function of philosophy is to stimulate the formation of theory from which testable hypotheses may be deduced. (1972:23)

Broudy, in the following statement, touches on the need for a comprehensive theory in education:

> This unifying principle is a theory of education which rationally weaves together the objectives of the culture, life outcomes, school outcomes, the training of teachers, specialists and administrators, as well as the facilities and resources by means of which the whole enterprise goes or falters. The consistency of this theory, its inclusiveness and sophistication, its faithfulness to the demands of the culture, to social reality, to the facts of pedagogical life constitute criteria for curriculum decisions that transcend establishments. It is, I shall argue, the only rationally defensible basis for educational decisions. (1966:18)

Without such an integrative framework, educational practice will to a large extent remain ineffective. Fragmentation, frustration and the lack of meaningful experiences are frequent problems that plague teachers. The accumulated knowledge from experience and research findings has to be organized into a useable form and this cannot be done unless a coherent body of theory is formulated (Jordan and Streets, 1973). Information on human growth and development, learning, and teaching can be so organized that the classroom teacher has the benefit of a solid base from which to operate. A teacher can then be freed from being tied to specific instances and activities and can use the general theoretical principles as a guide to practice.

The continual interplay between theory and practice is well-stated by Belth:

> Most important, we are freed from the impossible distinction between theory and practice in educating. The study of education, then, can be the study of practice which is developed on the grounds of some definable, analyzable theory of man, knowledge, experience and value. (1965:35)

In this manner, theory guides practice, and practice informs theory. At its best, a theory should be predictive and if the predictions are not borne out, then changes have to be made in the theory. If education is viewed as a process of unfoldment of the developing individual, then educational theories have to be flexible and tentative so that new research findings on human growth and learning can be continually incorporated.

Tentativeness, relativeness and predictability are guiding principles in theoretical construction and reconstruction. The power of theories are most familiar in the natural sciences and in mathematics. Briefly, theories are sets of abstract, conceptual constructs from which inferences can be made about the world (Belth, 1965). A theory is a tool that aids in going beyond that which is directly observable. In some cases, theories are based on experimental evidence and said to be inductive; in other cases theories are derived deductively from fundamental propositions about the nature of reality, but they have to be substantiated inductively. For example, Einstein's general theory of relativity was deduced from propositions about the nature of gravity and light, but the theory was accepted after experimental confirmation.

Similarly, in education, what goes on in the child's mind cannot be observed but has to be inferred from behavior or products of behavior such as written work. In most cases, only content or factual knowledge can be assessed by tests or observation. However, since so much of learning and the effects of teaching cannot be seen directly, theories that are based on fundamental assumptions about the nature of the child and on research findings are essential.

The plea by science educators for a viable theory in science education can now be viewed in some perspective. Science education could be rendered more effective if there were a comprehensive theory about the nature of the child, learning and the teaching process. The challenge to science education is acute, as reflected in the words of Hurd: "We now have sixty years of cumulated research in science teaching and yet little notion of where we stand on practically any question" (1971:246).

The Philosophy and Theory of the Anisa Model[1]

The Anisa Model is the expression of the hope that it is possible to create a scientifically-based educational system that can equip parents, teachers and children with the power to be in charge of their own destiny. Anisa may be viewed as a socio-cultural endeavor whose aim is to show people how to obtain and use knowledge, so that not only will their own potential be actualized, but also, they can contribute to the betterment of the society in which they live. Such a task is not easy and comfortable. It calls for a sustained, prolonged and systematic effort that can effect changes in the traditional ways of perceiving, thinking, feeling and willing.

Over the last fifteen years efforts have been ex-

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[1]This brief discussion has been drawn from articles published on the Anisa Model, namely: D. Jordan and R. Shephard, "The Philosophy of the Anisa Model." World Order reprint 7(1) (Fall 1972P:23-31); D. Jordan and D. Streets, "A New Basis for Educational Planning," Young Children 28(5) (June 1973):289-307; Jordan and Streets, "Guiding the Process of Becoming: The Anisa Theories of Curriculum and Teaching," World Order reprint 7(4) (Summer 1973):29-40. Every major proposition will therefore not be documented.

erted in the direction of establishing the fundamental premises of the Anisa Model. An explicit philosophy with carefully defined first principles forms the foundation upon which the Anisa Model rests. The process or organismic philosophy of the philosopher, mathematician and logician, Alfred North Whitehead, was adopted in an attempt to transcend the limitations of a mechanistic and materialistic view of man. Whitehead's philosophy of organism serves to highlight those features that are characteristic of man, such as consciousness, will, purpose and creativity. An organismic perspective is essential and vitally needed if we are to view education as the process of drawing out the latent, inherent potentialities of every individual. Man's growth or becoming is characterized by the continual translation of potentiality into actuality such that the primary focus of development is on process rather than static actuality.

The organismic philosophical perspective served as a framework so that the accumulated knowledge about human growth, development and learning could be synthesized into a comprehensive, coherent, and logical body of educational theory. Explicit theories of development, curriculum, teaching, evaluation and administration have been derived from the basic philosophical principles and address the issue of how the actualization of potential may be effected.

The Anisa theory of development identifies two basic categories of potentialities: biological potentialities which are released through proper nutrition, and psychological potentialities which are actualized through learning. Psychological potentialities may be further classified as psychomotor, perceptual, cognitive, affective and volitional potentialities. The separation and distinction amongst the different categories of psychological potentialities was made only for the ease of understanding and fostering a particular dimension of development; it is fully understood that every act of experience will involve all five categories, each to a greater or lesser extent. The theory affirms that development as a whole is sustained through interaction with the environment. Thus the quality of environment influences the quality of the interaction which in turn influences development.

The theory of curriculum describes what information is to be learned (content), how it is to be learned (process), and what children do to learn both content and process. Content curriculum goals are organized around the hierarchical classification of environments--in ascending order from mineral, vegetable, animal, human to the unknown. A grouping of the first three environments represents the physical environment (the realm of natural science). Process curriculum goals are arranged around the categories of psychological potentialities, so that in interacting with the environment, psychomotor, perceptual, cognitive, affective and/or volitional processes may be actualized.

In interacting with the environments, a learner will utilize three interrelated symbol systems: mathematics, language, and the arts. Some environments may be mediated predominantly by one mode of symbolization, whereas at other times a combination of modes may be used.

Potentialities, when they are actualized, are expressed as patterned uses of energy. When the learning of some content is fused with the patterned use of energy (process), attitudes and values are formed which reflect the character and personality of the learner. Interaction with the physical, human and unknown environments results in the formation of material, social and philosophical values respectively. Upon these values rest the higher order competencies, that is, technological, moral and fiducial. The combination of the three higher-order competencies results in self-competence or personal effectance, i.e., learners who are self-competent, with balanced and well-integrated personalities who can take charge of their own learning by knowing how to apply their knowledge to life.

In searching for an integrative system that could answer some of the issues facing science education, I found the comprehensiveness, conceptual clarity and coherence of the Anisa philosophy and theory to be particularly attractive (see Figure I). Since the focus of this dissertation is on science curriculum development, I feel that the Anisa Theory can serve a valuable function in the generation of a possible framework for the development of a natural science curriculum.

Science and the Actualization of Human Potential

The attempt to place education on a scientific basis has been a major goal of the Anisa Model. Accordingly, the study and the teaching of science occupies an important place in the theoretical framework of the Model. The remainder of this chapter will be devoted to an elaboration of some of the Anisa propositions as they relate to science and the investigation of nature, the process of symbolization, the formation of material values, the attainment of technological competence and its relation to moral and fiducial competence.

Purpose of Science

Throughout recorded history man has been driven by his quest for explanations and answers about the phenomena in the physical world. This process of inquiry, together with the desire to know and to understand, was the impetus to the rise of modern science. Not only is there the

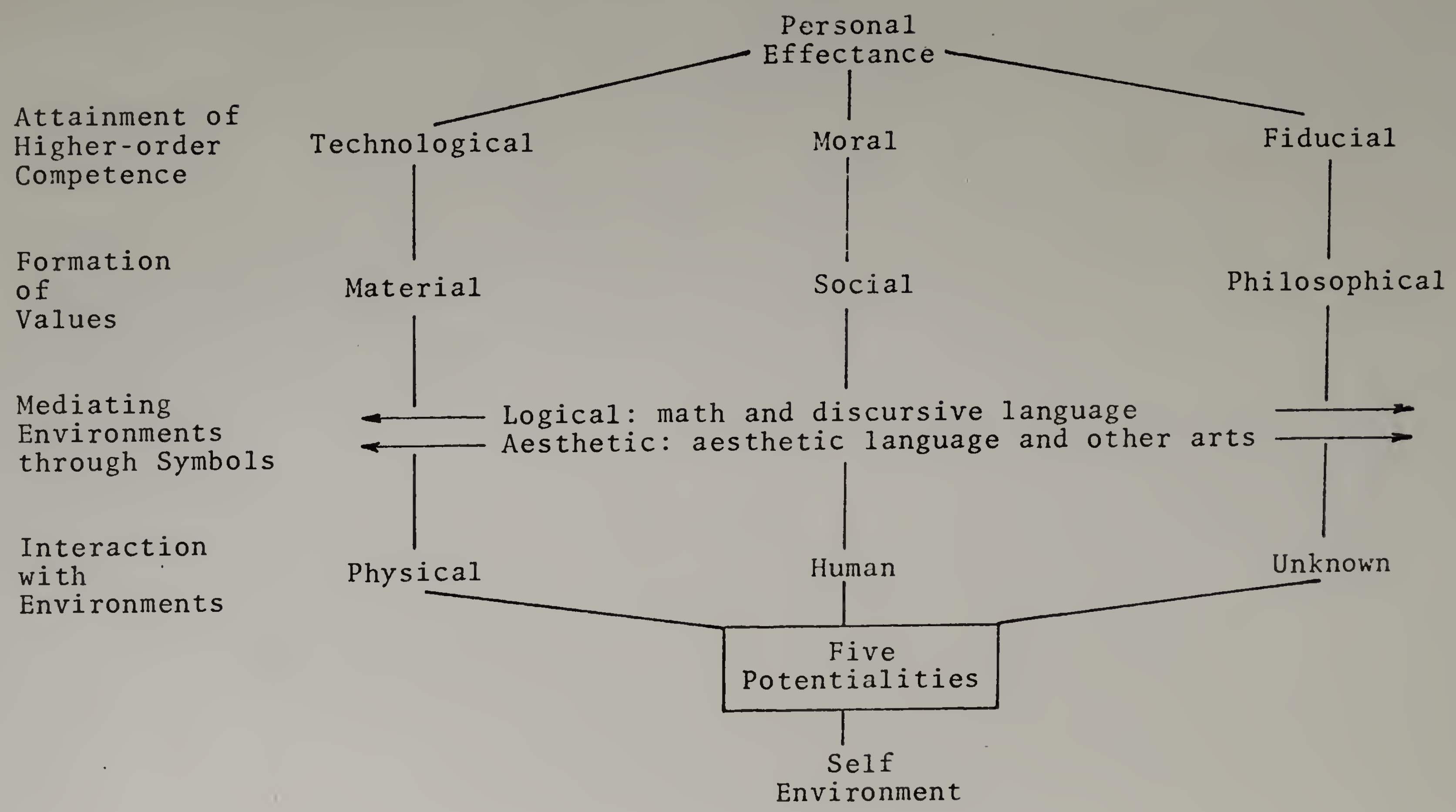

Figure I: Theoretical Framework of the Anisa Model search to know why and how things happen, but there is also the drive to find relationships between events and see how all events are integrated into the unity of existence. Bronowski, in describing the scientific endeavor, says that the goal is ". . . to find nature one, a coherent unity . . . that every research carries the sense of drawing together the threads of the world into a patterned web" (1967:138).

The desire to explore, to discover order and patterned relationships has been amply demonstrated and documented in the field of psychology and is worth reviewing briefly. One can understand the power of the need to find and create order when its relationship to survival is made more evident. Gibson (1967), in her extensive work on perceptual learning, states that out of the welter of stimuli that impinge on the sense organs, the organism extracts certain bits of information. It is the detection of the distinctive features of objects and events and their patterns of invariant relations that is of most value to the organism. These invariant features and relationships aid in the reduction of uncertainty and hence create order and a sense of predictability and stability. The organism or the individual gains meaning from ordered events and not from disordered or chaotic situations. In the continual reduction of subjective uncertainty, survival can be sustained and enhanced. Reinforcement for the detection of of invariants may be provided by external rewards or knowledge of the results but primarily the satisfaction is internal.

Psychologists, such as Berlyne (1966) also suggest that curiosity and exploration act as strong internal motivating factors. Berlyne found that there were two kinds of exploratory responses. Firstly, specific exploration occurs when an organism is disturbed by lack of information and thus left prey to uncertainty and conflict. Activities such as science, philosophy and mathematics bear a close affinity to this type of exploration, with curiosity being the motivating factor. Secondly, diverse exploration is of a more general type where what is sought is an optimum amount of novelty, surprise, complexity, change or variety. Berlyne has investigated this latter type in many experiments with subjects ranging from young infants to adults. Complexity, irregularity and incongruity of pattern was investigated. An optimum range of these factors increased exploratory behavior, but if they were extremely irregular, then the responses declined. Even babies of 3-9 months were attracted by patterns that were more complex as these possessed more internal contour.

In man the spirit of inquiry into nature is more than the desire to know and to understand. It also entails the sense of achieving mastery or gaining control over nature by applying its laws.

In his classic paper on "Motivation Reconsidered: The Concept of Competence," White (1959) reviews the various theories of motivation based on primary drives and presents a new conceptualization which accounts for the previous gaps. Competence is defined as "an organism's capacity to deal effectively with its environment" (White, 1959:297). Exploration, play, manipulation and producing changes serve to create a certain "feeling of efficacy" in dealing with the environment, a sense of mastery and satisfaction over environmental situations. These types of activities lead the organism to discover how the environment can be changed and the consequences that flow from these changes. The motivating force behind such behavior is what White terms "competence motivation" or effectance. It is directed, selective, persistent and satisfies an intrinsic need to deal effectively with the environment. Above all, this view of effectance has adaptive and survival value.

A further discussion by Whitehead on the role of curiosity helps to make the connection between the impelling power of curiosity and the conceptual understanding that accrues from such a drive. In the following quotation, he extends our conception of curiosity and endows it with added significance:

> . . . the word 'curiosity' somewhat trivializes that inward motive which has driven man. In the greater sense . . . 'curiosity' means the craving of reason that the facts discriminated in experience be understood. It means the refusal to be

> satisfied with the bare welter of fact, or even with the bare habit of routine. The first step in science and philosophy has been made when it is grasped that every routine exemplifies a principle which is capable of statement in abstraction from its particular exemplification. (1967a:141)

The statement of general principles in abstraction from the immediate facts stand as a testimony to some of the greatest achievements of the mind of man. Broad, generalized propositions that could be articulated led to the formation of theories and laws about the working of nature. Having general theoretical conceptualizations about the numerous events in the physical world has allowed man to display a sense of mastery or competence in dealing with natural phenomena. Through these theories man now has the power to test out possible consequences of certain events, make predictions about novel events and plan and choose alternative routes of inquiry and action. He can make what Whitehead calls "the creative advance into novelty."

The purpose of science in the conceptual, intellectual and theoretical vein may be seen as possessing a transcendent function: philosophical and theoretical knowledge about nature provide man with a vehicle with which he can transcend his present lack of understanding and perpetually move beyond into the realm of unknown possibilities.

Application of theoretical knowledge in uplifting the quality of life of mankind is also an important function of science. The distinction that is frequently made between 'pure science' and 'applied science' is artificial and unnecessary. Both areas feed each other, as is evident in Whitehead's statement about the rise of modern science: "Invention stimulated thought, thought quickened physical speculation" (1976c:5).

Much of the poverty, disease, and ill-health in the world have been successfully attacked by advances in science. Scientific and technical progress have certainly given men all over the world visions of the power of science. However, for all the advances in science and technology, the level of the conscious awareness of preserving the earth as an inhabitable planet has yet to be realized. Pollution, depletion of energy resources, and the threat of nuclear destruction haunt us daily. As Huxley says, " . . . the human race is, in fact, surrounded by a large area of unrealized possibilities, a challenge to the spirit of exploration" (1957:15). The time has certainly arrived when the challenge to discovery and invention has to be closely allied to moral concerns. Science does not exist in isolation from the people--its true power lies in its capacity to enhance the quality of survival of mankind, both intellectually, emotionally and physically.

Mediation of the Physical Environment Through the Process of Symbolization

Interaction with any environment can be mediated by the use of symbols. One of the propositions of the Anisa Model is that there are three symbol systems which mediate our encounters with the world; namely, mathematics, language and the arts. Scientific investigation of nature depends upon the use of math and language (e.g., English terminology) primarily; the role of the arts per se is negligible except in the sense of aesthetic awareness and holistic integration of various events into some unitary experience, which is a vital concern in science.

The process of symbolization is defined by Marks (1976:91) as "the capacity to use (entities) symbols to represent abstractions (conceptions or meanings)."[1] The data of experience are received through perception (sight, hearing, smell and touch) and are repsented by symbols. A symbol is an entity that can stand for something else in the absence of it. For example, words, numbers, pictures or graphs are symbols.

For Whitehead any phase of human experience has two aspects--intellectual and aesthetic, i.e., the act of symbolization may be seen as logical and/or aesthetic (1968b; 1969).[2] Interactions which are designed to insure

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[1]For a detailed elaboration of the role of symbolization and abstraction in the Anisa Model see Marks (1976).

[2]Current developments in the Anisa Model center around the explication of the logical and aesthetic modes of symbolization. Since these developments are still in process, this dissertation will not dwell on these facts in great detail.

control of the environment depend on scientific understanding and this is only possible when symbols are used to sustain logical modes of thought. Logical modes of symbolization are used as a means of expressing the 1:1 correspondence between appearance and objective reality, i.e., the representations are as accurate, precise and true to the original as possible. The scientist in the logical investigation of nature is analytic and endeavors to be as objective as possible. However, it is fallacious to assume that scientists are wholly objective in their interactions with the physical environment. From an interactionist point of view, the unity of experience is exemplified in the integrated action of the subjective and the objective, the internal and external states of the organism. The nature of scientific thought is marked by the interplay of these two elements: while a scientist attempts to be as objective as possible in the light of the given evidence, he is nonetheless continually guided by inner, subjective states--purposes, intentions, aspirations. Despite its air of strict empiricism and objectivity, science can be understood as a deeply humanistic endeavor. Polanyi, in a discussion on objectivity in science, recalls how scientific theory came to be reduced to a "convenient contrivance" in the modern mind. It appears, however, that reality as painted by science cannot escape being viewed from a singularly human perspective. He claims that

> as human beings, we must inevitably see the universe from a center lying within ourselves and speak about it in terms of a human language shaped by the exigencies of human intercourse. Any attempt rigorously to eliminate our human perspective from our picture of the world must lead to absurdity. (1958:1)

The human perspective that Polanyi speaks about may be seen as the aesthetic mode of symbolization in the scientific process in inquiry. Aesthetic symbolization serves as a means of expressing the subjective or internal phase of human experience. The logical analysis of nature is accompanied by an intimate sense of awe, wonder and joy in the harmony of existence. A scientist expresses this subjective experience of nature in the elegance and beauty of the mathematical formulations or in the simplicity of general principles.

On the one hand, it is true to say that scientific inquiry is primarily a logical, rational, and analytic process, but on the other hand it is inadequate because it fails to account for the integrative and holistic aspect of thought. The problem appears to be one of emphasis and purpose rather than deliberate exclusion. In the logical and aesthetic modes of symbolization, the purpose for the expression is different and therefore the principles of translation or method of representation also differs. A scientist will use precise, systematic, mathematical formulae to describe the laws of gravity whereas the artist may write a poem, paint a work of art of create a dance to describe the same law. The scientist will rarely use aesthetic symbols to express his discoveries but only logical symbols like language and mathematics. However, the general frame of reference within which he operates proceeds from aesthetic assumptions such as the order of nature and the unity of all existence.

The patterns in nature are represented symbolically in a variety of ways by scientists: mathematical formulae and graphical representations describe the relationships between phenomena in the physical world; accurate works or treatises are written about the principles and laws of physics, chemistry, biology and geology; and diagrams which are precise, pleasing in appearance and true to form are used to represent plants, animals, molecular structures and geological formations. In all these instances, the goal is to clarify the 1:1 correspondence between appearance and reality.

Whitehead's philosophy expressed the relationships among the notions of appearance, reality, truth, beauty, science and art. He says that the method of investigation in science is dedicated to the pursuit of truth. The meaning of this is made more explicit by Whitehead (1967) in his discussion of appearance and reality: reality is that which exists or that which is. Appearance is only an "incredibly simplified edition of reality"--what is seen or observed is limited to our human way of looking and understanding. The measure of truth exists insofar as appearance corresponds with reality, which of itself can never be known directly. Whitehead writes that "Truth is the conformation of Appearance to Reality. This conformation may be more or less, also direct or indirect" (1967:241). Experimentation and investigation can make closer and closer approximations to the way things are and so present a clearer picture of events in the world. Scientific laws are never more than an approximation to the truth, although at times it may be a very close one (Huxley, 1957).

Beauty, for Whitehead, is "the mutual adaptation of the several factors in an occasion of experience" (1967:252); that is, it represents the integration of various items into a patterned unity of experience. Integration, pattern and unity are elements of order and in this sense the scientist's search for the order of nature is the pursuit of beauty. At a deeper and less obvious level, the universe is harmoniously well-ordered, which makes Whitehead's claim fitting: "The teleology of the Universe is directed to the production of Beauty" (1967a:265).

Traditionally, beauty has been associated only or primarily with artistic pursuits and the implication is that science and art are somehow incompatible. Bronowski says that the dichotomy between science and art has been one of "the most destructive modern prejudices" (1967:9), and C.P. Snow (1959) has amply described the schism in his book <u>The Two Cultures</u>. Science and art, when truly significant, incorporate both truth and beauty. For the scientist, the discovery of the laws of nature is a beautiful truth, and for the artist, a work of art is a truthful beauty.

Role of Mathematics in Science

As mentioned previously, the primary means of inquiry in science is through the processes of logical thought that can be clearly symbolized. Language and mathematics are the tools of the scientist. However, at higher and higher levels of generality, mathematics becomes the indispensable instrument of explanation and expression.

Historians and philosophers of science concur on the point that the rise of modern science in the 16th and 17th centuries would not have occurred without mathematics (Whitehead, 1967c; Butterfield, 1965; Kemeny, 1969; Cassirer, 1944; Toulmin, 1960). A concise and brief description of the history of mathematics can be found in Whitehead's work (1968a:285-286; 1967c:19-37). The Greeks were thought to have created the sciences of geometry and number by reviving and expanding some of the pre-existing ideas from the Egyptians and the Phoenecians. Pythagoras was the first man to have delved into an understanding of the importance of number as an abstract entity. From the medieval period until today, the most sophisticated forms of mathematical theories have been developed: algebra, trigonometry and differential calculus to Riemannian geometry and catastrophe theory. In most instances of scientific discovery, new forms of mathematical equations had to be developed to fit the observed facts, e.g., Heisenberg discovered matrix calculus, which was invaluable in calculating some of the properties of atomic systems; Von Neumann extended Heisenberg's conception to a statistical matrix calculus which combined the basic propositions of quantum mechanics and probability theory (Margenau, 1950). Sometimes, mathematical structures are entirely deduced to explain the harmony of the world. Piaget, as an eminent mathematician and logician in trying to explain the harmony that exists between mathematics and the real world, says:

> . . . deduction sometimes takes place before and not after the experiment, that is, in anticipation . . . But even more striking and more common is the construction of purely abstract mathematical structures, which afterward serve as indispensable frameworks for physical phenomena, without having been intended as such beforehand. Well-known examples of this are Riemann's expression of space and Einstein's use of tensorial calculus as well as the many geometric and algebraic models used in microphysics. (1971:341)[1]

The key phrase in the above quote is the "construc-

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[1]Einstein, in the early 40s, suggested to Piaget that an investigation of the child's understanding of time, velocity and movement would be of interest to epistemology. Piaget then published The Development of Child's Conception of Time and The Development of the Child's Conception of Movement and Speed (Ginsburg & Opper, 1969).

tion of purely abstract mathematical structures." To abstract or the process of abstraction is the power that underlies symbolization. According to Marks (1976), the word abstract or abstraction commonly refers to ". . . thought that entertains ideas and that is based on but is essentially divorced from concrete experience" (p. 47) and may be taken literally to mean the separation between the actual and the ideal. The scientist's capacity to anticipate as expressed in the above quote by Piaget reflects the ability to think in terms of the ideal state or the possibilities that could be. The formulation of the great theories and laws in science could never have been achieved without man's capacity for abstraction and the urge to transcend his present state of knowledge and move into the realm of potentiality. Hypothetico-deductive thought allowed Galileo to conceive of a purely isolated system (which never occurs in nature) and which led to his science of dynamics (Cassirer, 1944:49; Whitehead, 1967c:46).

Einstein, in his autobiography, discusses the power of abstract thought in investigating nature and the "free play with concepts:"

> Out yonder there was this huge world, which exists independently of us human beings and which stands before us like a great, eternal riddle, at least partially accessible to our inspection and thinking. The contemplation of this world beckoned like a liberation . . . The mental grasp of this extra personal world within the frame of the given possibilities swam as highest aim half-consciously and half-unconsciously before my mind's eye. (1970: 5)

Heisenberg (1971) reports on Einstein's remarkable "thought experiments" which reflected his mental grasp of the inmost essence of physical phenomena. In the early days of the formation of the uncertainty principle, Einstein would present innumerably imaginary experiments to refute the new law. He would present an experiment at breakfast, and if after a whole day of discussion the uncertainty principle was not shaken, by next morning he was ready with a new imaginary experiment more complicated than the previous one.

Much of the emphasis in Piaget's work has been on the development of abstract conceptual thought in children. Piaget (1970a) describes the understanding of logico-mathematical relations as the most basic form of knowledge. The young child, in learning to conserve, has to learn that certain aspects of objects remain invariant even after transformations occur. The qualities of number, substance and area have to be abstracted from the perceptual input and held in the mind's eye though changes take place in the environment.

The notions of abstraction, ideal, actual and good in relation to mathematics was first explored by the Greek thinkers. The Greeks instinctively searched for general abstract principles that explained the nature of reality (Whitehead, 1967c) and it was Pythagoras, who in his study of music, discovered the independent existence of ratios between numbers that could express musical intervals (Cornford, 1971). It was Plato, however, who maintained the overwhelming importance of math in relation to the ideal forms in nature--he continually sought for the "forms in the facts" (Whitehead, 1969:25). In a discussion on "mathematics and the Good," Whitehead notes that

> Human intelligence can conceive of a type of things in abstraction from exemplification. The most obvious disclosures of this characteristic of humanity are mathematical concepts and ideals of the Good--ideals which stretch beyond any immediate realization.
>
> Any practical experience of exactness of realization is denied to mankind: whereas mathematics, and ideals of perfection, are concerned with exactness. (1968a:104)

The abstract formal properties of mathematics are exactly suited to the scientific description of events. Abstractions help us to deal with the forms of relationships or with the unchanging aspects of reality. Whitehead, as a mathematician with few equals, explains the abstract nature of mathematics in a clear manner.

> . . . it applies to everything, to tastes and to sounds, to apples and to angels, to the ideas of the mind and to the bones of the body. The nature of the things is perfectly indifferent, of all things it is true that two and two make four. Thus we write down as the leading characteristic of mathematics that it deals with properties and ideas which are applicable to things just because they are things, and apart from any particular feelings, or emotions, or sensations, in any way connected with them. This is what is meant by calling mathematics an abstract science. (Whitehead, 1972:2)

Scientific laws are usually expressed in the form of mathematical equations because they exemplify the operation of general principles apart from every specific instance. Discovery of patterned relationships in nature is what concerns the scientist and "Mathematics is the most powerful technique for the understanding of pattern, and for the analysis of the relationships of patterns (Whitehead, 1968:109).

Dealing in the realm of abstract principles confers upon science its power of prediction and explanation. Consequences of events and alternative solutions can be conceived of theoretically before the events actually transpire. Man is thus able to gain control over the physical environment and endeavor to enhance and sustain the quality of life of mankind.

Whitehead sounds a cautionary note in relation to science and abstraction. The procedure of analysis in exact thought is vital and necessary but " . . . it weakens the sense of reality"(1968a:113). By this he means that science investigates parts of reality but a more comprehensive philosophical scheme is needed to interpret all aspects of the ultimate nature of reality.

Science education, then, should infuse children with a sense of the truth and beauty in nature. Mathematics and language are necessary logical tools for expressing the precise cause and effect relationships in physical events. However, the aesthetic mode of symbolizing the imaginative joy in the beauty and harmony of nature should not be neglected.

Formation of Material Values Through Scientific Inquiry

Since the formation of values is a characteristic of man and the Anisa Model is concerned with the actualization of human potential, it necessarily addresses the role of values and attitudes in the development of the individual. The Anisa theory of value formation has been elaborated upon by Raman (1974). The aim of this section is to review the major propositions of the Anisa value theory and to try to make explicit the kinds of values, attitudes and feelings that are actualized through scientific inquiry into the physical world.

Trying to find a definition of the term 'value' presents a bewildering task because the word has been used in so many ways. The Oxford Dictionary (1971 edition) has numerous meanings for 'value' but the one that is applicable to the present context is: "the relative status of a thing, or the estimate in which it is held, according to its real or supposed worth, usefulness or importance." Most people would associate value with something that is deemed to be worthy or important. The problem with this commonly-held view is that it is not always possible to discern the values that a person holds because there is a lack of congruence between value statements and acts of behavior. Very often, the behavior that is observed is exactly the opposite of a value that is verbally claimed to be strongly held.

An operational definition that appears to be more useful has been suggested by Jordan and Streets (1973) and Raman (1974). These authors state that interaction with the environment occurs in a patterned manner and that the resulting actualization of potential or the release of new energy for use by the individual is structured in certain ways. The new energies are not expressed in a haphazard or random manner, but in a patterned fashion. A value, then, may be defined as relatively enduring patterned uses of energy such that it reflects certain new ways of perceiving, thinking, feeling, intending and doing things. This definition allows one "to see" what values a person holds because energy will be expended in ways that are observable and predictable, i.e., the energy use defines the values.

Interactions with the different environments, i.e., physical, human and unknown, are characterized by different patterns of energy utilization or values. Patterns of interactions with the physical environment are material values. Social values are defined as those aspects of interactions that relate to the human environment. Patterns of interactions with the unknown environment are called philosophical values.

In order to define material values, it is necessary to define the term "physical" environment more closely. The term "physical" refers to those aspects of the environment which human beings can interact with and which can be analyzed in terms of efficient causation. This definition does not include those elements of the environment and those interactions with the environment which can only be effectively explained in terms of psychological causality. For example, in the human environment, there are aspects of the human body which can be analyzed in terms of efficient causation and which would be the subject matter of natural science. However, there are important aspects of human beings that can only be analyzed effectively in terms of psychological causation and therefore would be dealt with in the social sciences (psychology, sociology, anthropology, etc.).

Material values, then, focus primarily on the efficient causation aspect of interactions. This does not mean that final causation, purpose of internal determination is excluded in efforts to understand the nature of physical events. As discussed in Chapter II, it is necessary to consider both efficient and final causation if one is to truly understand physical phenomena.

Given the Anisa definition of value as the relatively enduring patterned utilization of energy, it is not possible to say whether particular values are more desirable or less desirable until some relative standard, criterion or ideal has been established. One such relative standard adopted by the Anisa Model is whether or not values (energy uses) are effective in gaining mastery and control over one's interactions with the environment. Robert White's (1959) paper on competence motivation is helpful in understanding this idea. He identifies competence or effectance as the ability to interact as effectively as possible with the environment so that a sense of mastery is achieved. Because competence enables one to control one's interactions with the environment and so enhance the quality of survival, White postulates that human beings will be intrinsically motivated to attain competence. Some values then can be judged as being more effective or less effective to the extent that they help or deter a person from interacting effectively with the environment. Therefore, competence is one standard or ideal against which values can be judged, and may be defined as the optimal organization of energy utilization to achieve particular objectives.

To insure the best use of their energy, scientists put their efforts into trying to expose the fundamental relationships or patterns of relationships among events in the physical environment. One can say that the utilization of their energy is organized around the discovery of the fundamental laws and principles of science. These laws and principles are usually stated as "optimal formulations," that is, they reflect the best possible statements of the patterned relationships among physical events under ideal circumstances.

In fact, some of these laws and principles which have been articulated in natural science are stated in a form that explicitly reflects an optimal or ideal nature, e.g., the Ideal Gas Law. This law and other laws in natural science can be said to be ideal or optimal formulations because they describe relationships that obtain only under conditions that never actually exist. Hence, the relationships can never be observed exactly. Laws and principles are ideal statements of relationships which can be confirmed by their increasing approximation to observed events.

The laws and principles of natural science are formulated on the basis of some ultimate ideals or fundamental assumptions. These ultimate ideals lure the scientist to reach out continually into unknown territories. Order, truth, beauty, elegance and simplicity are some of the ultimate ideals that guide scientists in the optimal formulations of relationships between events. Whitehead claims scientists hold an "instinctive conviction in the Order of Nature" (1967c:4). Watson, in describing the search for the structure of DNA, says that he was driven "by the belief that the truth, once found, would be simple as well as pretty" (1968:ix). All of the requirements of order, beauty, truth and simplicity reflect the overwhelming guiding influence of ultimate ideals in the formulation of scientific laws and principles.

Attainment of Technological Competence Through the Discovery and Application of Scientific Knowledge

Often, the word "technology" is viewed in a restricted sense as meaning machinery or weaponry. It is possible to place our understanding of the word in a larger context. According to the Oxford Dictionary (1971 edition), technology means "A discourse or treatise on an art or arts; the scientific study of the practical or industrial arts." The root word is from the Greek "teckne" which refers to an art or craft. Usually, the artistic element is excluded from our usage of technology.

Whitehead states that science consists of two levels: theoretical and practical, which correspond to what is most frequently heard "science and technology." He acknowledges the essential unity of the two when he says

> Science is a river with two sources, the practical source and the theoretical source. The practical source is the desire to direct our actions to achieve pre-determined ends. . . . The theoretical source is the desire to understand. . . . I most emphatically state that I do not consider one source as in any sense nobler than the other, or intrinsically more interesting. I cannot see why it is nobler to strive to understand than to busy oneself with the right ordering of one's actions. (1967b:103-104)

The practical and the theoretical are inextricably interwoven. In the above quote the "right ordering of one's actions" in science derives from the logical and coherent theories that are formulated and then put to use in the proper manner that can be of service to mankind. It would appear that Whitehead's comment in relation to the practical side of science involves a moral concern, particularly in relation to how scientific knowledge is used. Certainly, the word technology today carries connotations of automation, war and destruction. The goal of the Anisa science curriculum is to harmonize the desire to understand the physical world and to direct the resultant knowledge to practical and useful ends.

Historically, the modern scientific revolution came about largely throughout "the merging and mutual stimulation of the separate traditions of scholarly, speculative science and experimental craftsmanship and technology" (McKenzie, 1973:7). The rise of the industrial system in the 17th century stimulated thought and this in turn increased the investigation into the laws of nature (Whitehead, 1967c; Butterfield, 1965). In the times of the Egyptians, even though astronomy involved systematic observation, technological advances were not made because there was no practical impetus to experiment. Similarly, the Greeks took the first steps in abstraction and generalization, but the Greek intellectual "desired to understand the world rather than control and change it" (McKenzie, 1973:4). Invention or practical uses of knowledge really began in the 16th century with mining, metallurgy, and the creation of waterwheels, which led to the early growth of the factory system. Together with the rise of experimental science in the 17th century and movement of the Renaissance, modern science and technology was firmly established.

Today, in the late 20th century, the intellectual rift between what is called "pure science" and "applied science" is evident. The former term implied knowledge for the sake of knowledge and is thought to be better than the application of the knowledge. The fallacy of this type of reasoning is that neither science nor technology can exist without each other. What needs to be made clear is that both pursuits are infused with the element of artistry--that form, elegance, harmony, simplicity and beauty are fundamental guiding principles in the practical and theoretical aspects of science.

It is clear from the preceding discussion that the original usage of the word 'tekne' included a meaning that was based on the ideal of artistry or beauty. Therefore, in the Anisa Model, competence in discovering and applying the laws and principles of natural science is called technological competence.

Definition of Technological Competence

Technological competence can be defined as the conscious ability to understand, discover and apply the optimal formulations, or the laws and principles of natural science in such a way that it maximizes the capacity to interact effectively with the physical environment. Technological competence also includes the ability to interact effectively with the physical environment in a way that gives one the feeling that the quality of one's viability is enhanced. Since effective interaction with the physical environment is related to one's feeling of enhanced viability, the definition of technological competence can be seen to include both objective or logical, and subjective or aesthetic, elements.

The logical aspect of the definition of technological competence is related to the accurate formulation of laws and principles in relation to the physical environment such that there is a one to one correspondence between appearance and reality. The laws and principles of natural science may be called optimal formulations because they reflect the most perfect or the best representation of physical events at this point in time in the intellectual evolution of man. As we develop better instruments for observation and measurement, and can refine our descriptions of relationships among events, then the laws and principles will be further developed to accommodate the new insights.

Describing relationships in terms of efficient causation is a logical process, i.e., it involves analytic thought processes. As mentioned previously, final causation is also vital in understanding the operation of the universe. However, the relationships involved in final causation are quite complex and are more difficult to identify clearly. Efficient causation is a description of physical cause and effect relationships in which there is some kind of transfer or transformation of energy so that two or more events are necessarily connected. This connection may be quite complex and may require explanations in terms of interaction rather than in terms of simple linear succession of events. However, the relationship will always be explained in terms of efficient causes. Since the laws and principles describe cause and effect relationships, it could be said that they describe the transfer or transformation of energy in physical events.

The non-logical, subjective or aesthetic aspect of the definition of technological competence is related to the notion of enhanced viability in both a theoretical and practical sense. An optimal formulation is the best possible theoretical formulation of a relationship (or relationships) among events such that order, beauty, elegance, simplicity and harmony are reflected in the statement of the relationship. The intuitive sense of order, and the organization of elements in an elegant and simple style depends upon the scientist's subjective or aesthetic awareness. There is a 'feeling' that the diverse elements fit together in a unified manner, and give an impression of beauty and wholeness.

The practical part of the subjective experience is that because one is effective--can make things work--there is a feeling of enhanced viability when the optimal formulations are applied in interactions with the physical environment. A person who can apply the laws and principles of natural science will have a sense of mastery of competence in being able to interact effectively with the physical environment.

A law or principle, if it meets or fulfills all the aesthetic requirements and the logical necessity of truth and accuracy, is said to be an optimal formulation. The test of the formulation, however, lies in practice, i.e., to whatever degree it works, then to that degree it is true, and if it is true then it should reflect the elements of order, beauty, elegance and simplicity. An optimal formulation can be applied in a manner that increases the quality of life and guarantees survival. The actualization of human potential then, on the one hand, finds expression in the attainment of technological competence, and on the other hand it is sustained by it.

Since technological competence is related to the lives and the actualization of potential of individuals in relation to the human environment, it must necessarily be constrained by moral concerns. For example, a murderer can be a technologically competent person because the principles of killing are well understood and can be applied in the best possible manner. However, when they are applied in this way, the viability of the victim is drastically reduced to zero. From the point of view taken in the Anisa definition of technological competence, we would say that the murderer is technologically competent but not morally competent because moral concerns are completely ignored. Ultimately, the overall viability of an individual or individuals is affected by the close relationship between technological, moral and fiducial competence. Thus, technological competence is a subordinate achievement whose ultimate value is determinable by appeal to moral (social) and fiducial (philosophical) concerns. These are briefly discussed in the next section.

Relationship Between Technological, Moral and Fiducial Competence

In the Anisa Model, the balanced and harmonious integration of technological, moral and fiducial competence results in personal effectance. A person who can understand, discover and apply the basic laws and principles which guide interactions with the physical, human and unknown environments so that viability is enhanced, can be said to have personal effectance. Usually the ultimate goal of growth and development is to achieve personal effectance.

Moral competence may be defined as the conscious ability to understand the basic principles of human interactions and to apply them in such a way that social viability is enhanced. Relating to people in a way that enhances their viability will reflect a certain level of moral competence.

Fiducial competence may be defined as the conscious ability to generate and be guided by fundamental assumptions or principles about the nature of ultimate unknowns. Such ability is based on faith. To the extent that these principles have a truth-value, they will, when applied result in enhanced viability. This competence has been called fiducial competence because effective organization of our interactions with the ultimate unknowns must be based on faith, trust, confidence or reliance. The word fiducial is derived from the Latin root <u>fiducia</u> meaning trust or confidence. Without fiducial competence, courage and hope are non-existent and fear is sovereign. Fear is an internal emotional state that influences interaction patterns and to the extent that it has no justification, it will impair development.

The detailed relationship between technological and moral competence, and technological and fiducial competence, will be discussed more fully in the following sections.

Technological and Moral Competence

The relationship between science and moral concerns surfaces when our knowledge of the laws of nature is put to practice. In the purely investigative activities and theoretical constructions in science, morality is not likely to be an issue. Polanyi, in describing the moral indifference that is appropriate on this level in modern science, cites Fisher:

> We attempt, so far as our powers allow, to understand the world, by reasoning, by experimentation, and again by reasoning. In this process moral or emotional grounds for preferring one conclusion to another are completely out of place. (in Polanyi, 1958:153)

Experiments are designed to discover valid relationships as they exist in the physical environment. Regardless of the scientist's personal moral convictions or emotions about reality, the experimental evidence is the final word. As Whitehead declares, there is a "remorseless inevitableness" (1967c:11) about the laws of nature.

However, in the application of scientific knowledge, the issue of morality assumes importance. There are, of course, moral and ethical questions involved in the type of experiments that are conducted by scientists, particularly in the fields of genetics and embryology. The concern here is the effect of the application of scientific knowledge on the lives of men, women and children all over the world.

The Anisa Model would maintain that to be a technologically competent person is a necessary but not sufficient qualification for a fully actualized human being. Being aware of the impact of the application of one's knowledge on other human beings is equally vital. Thus moral competence must be acquired along with technological competence. To be morally competent means that in one's encounters with other people, one endeavors to behave in a manner such that the needs, emotions and actions of others are taken into consideration.

Because of the implications of scientific knowledge for the survival of society and the individuals within it, moral standards cannot be ignored by scientists. The view that science is amoral, that it is without morality of any kind, is tied to the technical exploitation of knowledge. Large-scale industrial and economic concerns have contributed to the problems of pollution and conservation. The build-up of the world's arms race reflects the direct participation of scientists in activities that are not wholly conducive to uplifting the quality of the life of man. In a recent report in <u>Scientific American</u> (April 1976) it was documented that the cumulative total of the world's military expenditures between 1960 and 1974 was nearly four trillion dollars. The authors of this report stated that this potential for cataclysmic destruction represents:

> an immediate and heavy burden on the world economy. It is destructive whether or not the weapons are put to use in war. It contributes to inflation, retards economic and social development, and diverts resources urgently needed for human well-being. Until it can be put under control, it undermines the national and international security which it is intended to protect. (Scientific American, April 1976:54)

Einstein's comment in the following quote is worth noting. "Concern for man himself and his fate must always form the chief interest of all technical endeavor, in order that the creations of our minds shall be a blessing and not a curse to mankind" (in Andrews, 1974:380).

If scientists are technologically competent it does not necessarily follow that they will be morally competent too. A brilliant and successful methodology can breed an indifference to morality, right judgment and good conduct. Polanyi's insight into moral judgments and intellectual understanding is valuable.

> But moral judgments cut much deeper than intellectual valuations. A man may be consumed by an intellectual passion; he may be a man of genius, yet be also sycophantic, vain, envious and spiteful. Though a prince of letters, he would be a despicable person. For men are valued as men according to their moral force . . . (1958:214-15)

It is evident then that technological advances should be subservient to, and guided by, moral values, because ultimately all discoveries have an impact on the life of humanity. Von Bertalanffy's optimism is encouraging when he says that science "may still be able to present a grand view and become deeply humanistic in its endeavor" (1968b:68-69).

Science education has to meet the challenge of how to present science as a humanistic endeavor. Hurd states that "the task is to invent and then mould the future to suit human needs, but within a firm system of moral and ethical considerations" (1975:307). He goes on to say that with an emphasis on values, society, and technology, science education can become a reasonable venture with a future orientation.

Technological and Fiducial Competence

We continually confront unknowns in the course of our lives and instead of being paralyzed by the thought of not knowing something with certainty, we must learn to deal with such circumstances in some way. People who are crippled by contemplating the unknown future lack fiducial competence. Their effectiveness as individuals is greatly reduced or severely impaired. Those who do organize their lives effectively do so on the basis of faith. The idea of faith has religious connotations because one of the main purposes of religions has been to provide a framework for relating to the unknown on faith. Fiducial competence is often related to traditional functions of religion. However, in this dissertation, fiducial is used purely as a psychological term, and refers to the capacity to face unknowns through trust, which everyone must do, whether he regards himself as a religious person or not.

In a chapter on 'Religion and Science,' Whitehead presents a remarkable conception of the essential character of religion in general psychological terms:

> Religion is the vision of something which stands beyond, behind and within, the passing flux of immediate things; something which is real, and yet waiting to be realized; something which is a remote possibility, and yet the greatest of present facts; something that gives meaning to all that passes, and yet eludes apprehension; something whose possession is the final good, and yet is beyond all reach; something which is the ultimate ideal, and the hopeless quest. (Whitehead, 1967c:192)

He concludes by saying that religion "is an adventure of the spirit, a flight after the unattainable" that is not couched in safety and comfortable ways of thinking.

This insight into the nature of religion, when applied to the work of scientists in their eternal quest after truth in the vast unknown "which stands beyond" is clearly a fiducial act. The step into the unknown is marked by an act of faith. Whitehead (1967) states that scientists hold an instinctive conviction or instinctive faith in the order of nature; for Polanyi (1974) such convictions contain "fiducial elements," that is, trust or confidence in nature. Men have always tried to achieve definite convictions or form ideas about the material world. Polanyi says that "no part of the human race has ever been known to exist without a system of such convictions and it is clear that their elimination must mean intellectual death" (1974:23).

In essence, faith is courage in the face of uncertainty. Without this faith, trust, or conviction, scientists would be immobilized. The description by Polanyi of the dynamism of human faith seems to echo Whitehead's sentiments. Polanyi remarks that

> There is no way of approaching a hidden meaning than by entrusting ourselves to our intimations of its yet unseen presence. And such intimations are the only path toward enlarging and upholding our intellectual mastery over our surroundings. (1974:125)

The relationship between technological and fiducial competence is important because children have to learn how to relate to the world of physical phenomena, which for the most part are not directly observable or capable of being fully understood. There are always unknowns to be encountered. Einstein describes how as a child of 4 or 5 years of age, seeing the behavior of the needle of a compass made a deep and lasting impression upon him. His reaction as he recalls was that "something deeply hidden had to be behind things" (1970:9).

The insatiable desire to want to know about the world, the dedication to the pursuit of truth and the ability to have faith in the order of nature, are qualities that should be fostered in children so that the adventure of spirit can be kept alive and alert.

The next chapter will discuss the nature of scientific thought and its development in children as a preparation for the presentation of a possible framework for a natural science curriculum.

CHAPTER IV

THE DEVELOPMENTAL-EPISTEMOLOGICAL BASIS OF CHILDREN'S SCIENTIFIC THINKING

The development of a curriculum should be guided by ideas that explain how the child develops an awareness of the world, i.e., of people, of objects, of plants and animals. In particular, a science curriculum should be guided by information on a child's developmental understanding of physical reality or the natural world. How does a child come to think and know about physical phenomena? What are the distinguishing characteristics of the developmental sequence that can be of assistance to the curriculum developer? If a science curriculum is to meet the needs of children, developmental-epistemological considerations are absolutely vital, especially since all children, even though they are the same age, are not at all similar in their understandings, past experiences and attitudes.

Before launching into a discussion on children and scientific thinking, it will be useful to consider the epistemological basis of contemporary science, i.e., how do scientists, who reflect a mature level of thinking, come to know about physical reality? Essentially this question comes down to considerations of what scientists do to find out about nature. The reason for including this discussion on the scientist's thought is that it is always valuable to have a basis of comparison so that the dangerout fallacy of believing that a child is a miniature adult can be avoided. There may be similarities between how a child thinks about physical events in the world and how a scientist proceeds in his investigations, but essentially a child's thought is qualitatively different.

The Nature of Scientific Thinking

In reviewing the nature of scientific thinking, the question arises as to whether science is invention or discovery. Is the organized thought which we call science a construction of the human mind because of our need to represent the physical world in a meaningful manner to ourselves? Or, do scientists just describe what they see? To construct or invent means to devise, to build or to originate mentally; to discover means to find out, to reveal, to uncover. In practice, the scientist is both an inventor and a discoverer.

To find out what scientists actually do is not easy because they rarely write about the process itself. Scientists very seldom describe when precisely the hypothesis occurred to them or when it was that they made a prediction. One has to rely on the philosophers of science for accounts of the scientist's procedure or what is customarily called 'scientific method,' i.e., what is it that goes on in the head when discoveries are made. Medawar cites Einstein, who said that if you want to know what methods a theoretical physicist employs, stick closely to one principle: "don't listen to their words, fix your attention on their deeds" (Medawar, 1969:10).

Cohen and Nagel present a useful definition of scientific method, since it can be applied in many situations: ". . . scientific method is simply the way in which we test impressions, opinions, or surmises by examining the best available evidence for and against them" (1934: 192).

The method is the means by which scientists find out about events and the relations among events in the physical world. Such relations are found to be invariant and ordered, i.e., they are constant and remain so even under certain transformations. Scientists are primarily concerned with finding causal relations or causal order in the physical environment. The essence of a causal relationship is one event (B) occurs only, and always, when it is preceded by a certain other event (A) or events. Event A is then said to cause event B. The relationship always involves a transfer of energy in some form which necessarily connects the two or more events. Whitehead emphasizes the notion of physical causality in science when he says that there is

> . . . the inexpugnable belief that every detailed occurrence can be correlated with its antecedents in a perfectly definite manner, exemplifying general principles. Without this belief the incredible labors of scientists would be without hope. (1967c:12)

Ultimately a thorough understanding of the fundamental relationships inherent in and among phenomena leads to an articulation of the complex natural laws and principles which operate in the physical environment. The power to control the socio-cultural evolution of man lies in part in being able to predict the consequences of events in the physical world and to plan accordingly to meet the necessary changes. Understanding causation increases the probability that survival will be guaranteed and its quality continually improved.

Rise of the Scientific Method: The Role of Induction

Historically, the rise of the modern views on scientific method can be traced back to the work of Francis Bacon in the sixteenth century. Aristotle's powers of observation and description were admittedly the very earliest manifestation of some method but it was Bacon's work that initiated a formalized statement on scientific method. Bacon's view was that the simple deductive methods of formal logic could not by themselves lead to progress in science mainly because the rules of logic did not deal with discovery but only with the results of discoveries. His most important contribution was his awareness of the problem of induction, i.e., "how is it ever possible to conclude a material fact from another material fact?" (Fowler, 1962:42). The early Greeks had exercised a minimum of observation in drawing their conclusions. However, Bacon maintained that in dealing with the physical world, facts must be checked by observation of other facts and for every line of reasoning, experiments should be conducted. Fowler quotes Bacon as saying that "man can act and understand no further than he has <u>observed</u>" (1962:42). Even though he outlined the processes of scientific discovery, Bacon did not realize that in practice it is not possible to test every possibility. In this way, he neglected the guiding factors that assisted the scientist in selecting what to observe. Imagination, inspiration and guiding hypotheses were ignored in the act of discovery.

The next major contribution to scientific method was by John Stuart Mill (early nineteenth century). Mill maintained that the most vital task of science was to discover causes and that the notion of causation only could account for the observed sequence of events in nature. Fowler (1962) comments that Mill's main concern was to discover a method that worked in the natural sciences and then could be transferred to the social sciences. Mill formulated Four Canons that could serve as guides for experimental inquiry and focused on the relations between causes and their effects. In his outline of scientific proof, Mill refused to acknowledge the role of hypothesis. He felt that all scientific knowledge rested on pure induction alone. Classical inductivism in science arose from these positions taken by both Bacon and Mill, such that observation and experimentation were accounted for but not the role of hypothesis-formation.

Mill defined induction as "the process by which we conclude that what is true of certain individuals of a class is true of the whole class, or that what is true at certain times will be true in similar circumstances at all times" (in Fowler, 1962:74).

A clearer and more explicit definition of induction is given by Medawar. He states that "Induction . . . is a scheme or formulary of reasoning which somehow empowers us to pass from statements expressing particular 'facts' to general statements which comprehend them" (1969:23).

In both definitions, the emphasis is on the observation of concrete events and the articulation of a general rule or principle which could explain all the observed events. Focusing on the experiences of the senses only is in keeping with the tradition of strict empiricism, a view which states that if something is not verified by observation then it is meaningless. An empiricist perspective can only provide a simplified edition of reality because it only focuses on appearance. The limitations of totally objective knowledge is stressed by Whitehead when he notes that

> . . . the exclusive reliance on sense-perception promotes a false metaphysics. This error is the result of high-grade intellectuality. The instinctive interpretations which govern human life . . . presuppose a contemporary world throbbing with energetic values. It required considerable ability to make the disastrous abstraction of our base sense-perceptions from the massive insistency of our total experience. Of course, whatever we can do in the way of abstraction is for some purposes useful--provided that we know what we are about. (1967:219)

A major shortcoming of the inductive scheme is that science is made out to be a wholly logical and objective activity. According to Whitehead, such a rigid method "if consistently pursued, would have left science where it found it" (1969:7). Einstein himself commented that "There is no inductive method which could lead to the fundamental concepts of physics . . . in error are those theorists who believe that theory comes inductively from experience" (in Fowler, 1962:95).

A rigid, totally logical process such as induction fails to account for those internal, non-logical (outside logic) factors that can guide the scientist. Imagination, inspiration and intuition cannot be objectively accounted for, but they play a vital role in scientific research. In discussing the failure of the Baconian method of induction, Whitehead claims that

> What Bacon omitted was the play of a free imagination, controlled by the requirements of coherence

> and logic. The true method of discovery is like the flight of an aeroplane. It starts from the ground of particular observation; it makes a flight in the thin air of imaginative generalization; and it lands for renewed observation rendered more acute by rational interpretation. (1969:7)

Imaginative construction enters into the formulation of theories and hypotheses. In some cases there is an intuitive 'hunch' or just luck that guides observation; in other cases the framing of a hypothesis or a theory after observation is an imaginative act. Scientists have been known to dream of a solution to the problem, such as Kekule, who discovered the structure of the benzene ring. He dreamed of a snake catching its own tail in its mouth, thereby forming a ring. Polanyi, himself an eminent chemist and philosopher of science, describes scientific research in the light of non-logical and non-rational factors. He says that

> Though the task is definite enough, the solution is none the less intuitive. It is essential to start in science with the right guess about the direction of further progress. . . . All the time the scientist is constantly collecting, developing and revising a set of half-conscious surmises, an assortment of private clues, which are his confidential guides to the mastery of his subject. (1974:18)

Another criticism of the inductive view is the focus on facts alone. Very rarely does a scientist just collect facts upon facts. Even Darwin contradicts himself on this score. In his autobiographical sketch he claimed that he worked on "true Baconian principles" and just collected facts, but in a letter to a friend he wrote "I have an old belief that a good observer really means a good theorist" (in Madawar, 1969:11). Observational discrimination is a theory-laden enterprise and most authors agree with this view (Hanson, 1958; Madawar, 1969; Polanyi, 1974; Popper, 1962; Whitehead, 1967c). Observation is selective and is related to the needs and interests of the scientist via some working hypothesis or theory.

Modern Scientific Method: Induction and Deduction or the Hypothetico-Deductive Scheme

The predominant view of scientific method today is that it involves both induction and deduction as well as intuitive and imaginative processes. Traditionally there has been a history of opposition between the adherents of one view or the other. Deduction may be regarded as a scheme of reasoning that argues from the particular to the general and if properly executed from true premises can lead with certainty to the truth (Medawar, 1959). Mathematical theory is a deductive system that derives its theorems or proofs from true premises or axioms, and not by observation. Even Einstein claimed that "the supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction" (in Northrop, 1970:401). However, it seems pointless to focus on one or the other view since induction and deduction complement each other in the acquisition of knowledge about physical reality.

Scientific method as induction and deduction involves the triad of observation, hypothesis formation and experimentation. The first step involves observation of some event or phenomenon but no conclusions are drawn. Then the hypothesis (or hypotheses) is formulated on the basis of what is observed. Campbell defines a hypothesis in the following manner: "A hypothesis is . . . a proposition which is put forward for consideration, and concerning the truth or falsity of which nothing is asserted until the consideration is completed" (1953:290).

In Campbell's definition, the hypothesis is associated with doubt which consists of a suspense of judgment rather than the inclination to disbelieve. A description of how a hypothesis should be formulated is given by Cohen and Nagel. ". . . a hypothesis must be formulated in such a manner that deductions can be made from it and that consequently a decision can be reached as to whether it does or does not explain the facts considered" (1934:207).

Hypotheses can be regarded as suggested statements of possible connections between actual facts and imagined ones. Hence the truth or falsity of the hypothesis itself is never tested or directly verified. The hypothesis must, however, be stated in such a manner that predictions can be deduced from it and then tested experimentally. In this way, the hypothesis should finally provide an answer to the problem which generated the inquiry.

Confirmation of predictions is a vital part of scientific method. Cohen and Nagel describe the value of a prediction in the following quote. "The logical function of prediction is to permit a genuine verification of our hypotheses by indicating, prior to the actual process of verification, instances which may verify them" (1934: 210). Predictions indicate the power of the deductive system of thought--if the premises (that is, hypotheses) are true, then the conclusions can also be shown to be true, even before any experiments are conducted. A good example of this can be seen in Einstein's formulation of the general theory of relativity (1915) which made three predictions. The actual tests were not carried out until 1919 when all three predictions were confirmed.

Experiments or sets of experiments are designed to confirm the predictions and so verify or validate the hypothesis. A clear definition of verification is given by Cohen and Nagel. ". . . a function of verification is to supply satisfactory evidence for eliminating some or all of the hypotheses we are considering" (1934:210).

Rarely is there just one experiment that can eliminate one or all of the hypotheses. In most cases scientists proceed through numerous experiments, some relevant and some seemingly irrelevant, to arrive at some degree of certainty. A description of how Watson and Crick uncovered the structure of DNA shows the numerous set-backs suffered and hours of frustration spent over experiments that appeared to lead nowhere (Watson, 1968). However, the ultimate test of verification is the assurance that what is observed is as close an approximation to reality as can be, otherwise we shall be out of touch with reality and be led into error.

A theory may be viewed as a set of hypotheses or propositions (Campbell, 1953) and as such is neither true nor false. The overwhelming significance of a theory is that it exhibits systematic connections between events and is capable of deducing predictions that can be tested.

Science viewed as induction and deduction established itself as the official alternative to induction in the middle nineteenth century. Medawar describes the whole process as the hypothetico-deductive scheme, and the main modern advocate of this view is Karl Popper. The hypothetico-deductive scheme, as its name implies, places an emphasis on the role of the hypothesis--the formation of the hypothesis is the generative act in scientific research. The well-known philosopher, C.S. Pierce, said that "we must entertain some hypothesis or else forego all further knowledge" and that hypothetical reasoning "is the only kind of argument which starts a new idea" (in Medawar, 1969:46).

Porterfield echoes similar sentiments on the value of the hypothesis.

> Imagination is the method of hypothesis, and hypothesis is an indispensable aspect of scientific method. For the field in which the scientist works is a hypothetically constructed field. (1941:111)

Medawar presents a sound and useful synthesis of the various vital aspects of scientific method as it includes induction and deduction. He says that

> Scientific reasoning is an exploratory dialogue that can always be resolved into two voices or two episodes of thought, imaginative and critical, which alternate and interact. In the imaginative episode we form an opinion, take a view, make an informed guess, which might explain the phenomena under investigation. The generative act is the formation of a hypothesis . . . The process by which we come to formulate a hypothesis is not illogical but non-logical, i.e., outside logic. But once we have formed an opinion we can expose it to criticism, usually by experimentation; this episode lies within and makes use of logic, for it is an empirical testing of the logical consequences of our beliefs. (1969:46)

In the imaginative realm, the formulation of the hypothesis is a means by which possibilities are entertained. It is an inventive, creative and constructive phase. The critical episode provides the basis for verification, justification or validation of the ideas that have been entertained; it is a phase in which there is a discrimination of possibilities on the basis of empirical evidence.

The question posed at the beginning of this section sought to address the issue of whether science was invention or discovery. In reviewing the hypothetico-deductive method, it is evident that scientific method is concerned with the construction or invention of a system of beliefs about the world and that it is also concerned with discovering whether the system is as close an approximation to reality as possible. Braithwaite claims that science is invention and discovery when he says that

> Man proposes a system of hypotheses; Nature disposes of its truth or falsity. Man invents a scientific system, and then discovers whether or not it accords with observed fact. (1959:368)

The Interaction Between Hypothesis-Formation and Experimentation

Interactions between observation, hypothesis formation and experimentation are indispensable to scientific method as a regulative and self-corrective process. Feedback is provided such that the performance can be monitored by the consequences of the acts undertaken (Medawar, 1969). If the empirical evidence does not verify the hypothesis, then changes have to be made either in the original premise or in the experimental procedure. Such an active and dynamic view of thinking is very much in line with the work of Piaget. He says that

> Scientific thought, then, is not momentary, it is not a static instance; it is a process. More specifically, it is a process of continual construction and reorganization. (1970a:2)

Popper (1962) regards the continual interplay between conjecture and refutation as the self-corrective feature of science. His view is that conjectures (that is, hypotheses) are boldly put forward for trial and if they clash with the observations, they are refuted. Theories are tested with the hope of obtaining, if possible, a 'decisive refutation.' Popper also comments on how scientists may come to hold or formulate erroneous propositions. According to the traditional inductive views, error arises from a misreading of the facts in Nature either through blindness (poor observation) or prejudice. The consequence is that the inferences that are then drawn are mistaken. Such an account of the role of error in science is inadequate--theories are not, as a rule, found to be in error because of mistaken or poorly interpreted information. Usually, it is the contradictory evidence of new observations that highlight or indicate what the errors are in the theory that is currently accepted. The error does not lie in poor initial vision, but in the ideas which were previously held.

Scientific method, then, is a valuable means by which error can be taken out of our understanding of the physical environment, thereby improving our technological competence. Usually our thinking is of a routine character, and we are only shaken into doubt if something unfamiliar presents itself to us or if we are moved by curiosity. Most of our beliefs rest on the unquestioned acceptence of current modes of thinking about issues. Cohen and Nagel (1934) in an analysis of our beliefs, state that when we are challenged we resort to various methods, such as

(1) the method of tenacity, in which we cleave tightly to our system of beliefs and deliberately close out other evidence,

(2) the method of authority, which is an appeal to a highly respected source to substantiate the views that are held,

(3) the method of intuition in which propositions are self-evident to the individual only and to no one else, and

(4) the method of science or reflective inquiry which is a method that develops the utmost possible doubt and which calls for the best available evidence before a view can be accepted.

Cohen and Nagel continue that methods one to three are not free from "human caprice and willfulness." The authors' appeal is to scientific method.

> As a consequence, the propositions which are held on the basis of these methods [that is, 1-3] are uncertain in the range of their application and in their accuracy. If we wish clarity and accuracy, order and consistency, security and cogency, we shall have to resort to some method of fixing beliefs whose efficacy in resolving problems is independent of our desires and wills. Such a method, which takes advantage of the objective connections in the world around us, should be found reasonable not because of its appeal to the idio-

> syncracies of a selected few individuals, but because it can be tested repeatedly and by all individuals. (1934:195)

The Development of Scientific Thinking in Children

The preceding discussion examined the means by which scientists construct a meaningful picture of physical reality. Scientific thinking was found to be synonymous with scientific method, i.e., the actual application of scientific method is an external manifestation of internal thought processes. We come to know the nature of the thought of scientists by observing what they do and then drawing inferences about their patterns of thinking.

Similarly, the thought processes of children can be assessed most effectively by observing their actions and listening to the kinds of statements that they make in different situations. It was precisely in this manner that Jean Piaget developed his theories on how children think. Naturally, information on the internal thought processes of children is vital in the development of a science curriculum. Piaget's writings on the intellectual development are extensive, so only the most pertinent facts will be reviewed here to provide a context within which a child's developing notions of physical reality may be understood.

Development of Thinking in Children: A Piagetian Perspective

Piaget's theory of the development of thinking is essentially a constructivist-interactionist point of view. The influence on development is neither biological maturation nor environmental determination, but a combination of both. The resulting theory is an epigenetic one in which 'epigenesis' is defined by Piaget as the "sense of construction by interactions between genome and the environment" (1970b:710). From an interactionist perspective there is an interdependence between a knowing subject and the object to be known such that it is impossible to dissociate the "knowing subject" from the "knowable object" (Inhelder, Sinclair and Bovet, 1974). The development of psychological processes or patterns of thinking occurs through a continual interplay between the individual and the environment. The goal is to achieve some sort of equilibrium between the organization of psychological processes or structures and the functioning of these structures so that a reasonably stable picture of reality may be maintained. This is a dynamic equilibrium within which new pieces of information can continually be integrated in a holistic manner.

For Piaget, then, human knowledge is essentially active. Knowledge grows through the transformation of experience, not through the passive absorption of ideas presented by other agencies. The following quotes express Piaget's view of the construction of knowledge: "Knowledge results from continuous construction, since in each act of understanding, some degree of invention is involved" (Piaget, 1970a:77). "Actually, in order to know objects, the subject must act upon them, and transform them: he must displace, connect, combine, take apart, and re-assemble them" (Piaget, 1970b:704).

In the construction of a view of reality certain stable relationships are sought between objects or events. Gibson's work (1967) on the detection of perceptual invariance was discussed in Chapter III. The detection of patterns of distinctive features of objects and events and their invariant relations aided in the reduction of subjective uncertainty and so enhanced the survival of the individual. Bruner and his colleagues (1969) have postulated that the detection of invariant features of objects, events and people leads us to categorize or form classes so that a response is made in terms of class membership and not on the basis of each occurrence. For these authors, categorization is the major aspect of thinking and involves "an act of invention" (Bruner et al., 1969:2).

Piaget, in his book on <u>The Construction of Reality in the Child</u> (1954), identifies the major categories within which invariant relations are sought. These classes are the spatial and temporal field, and causality. Children gradually develop notions of invariance as they relate to features of objects (solids), liquids, weight, length, area, density, volume, time, speed, velocity, number, physical and psychological causality. The understanding of these concepts develops through stages that are essentially invariant and qualitatively different. Even though all children do not pass through the same stage at a similar age, the sequence of development is still invariant. At each stage, there is a qualitative difference in the thought of children. It is not a question of how much or how little children's thought resembles adult thought. The point is that children's thoughts are completely different from the adult way of thinking.

Four major stages of intellectual development have been identified by Piaget. These stages can be distinguished by the following characteristic ways of thinking (from Chittenden, 1970; Ginsburg and Opper, 1969):

Sensori-motor Stage (Birth to approx. 18 months). As the name implies, this stage is characterized by sensory and motor reflexive behavior. The infant learns to differentiate various features of the immediate environment and behavior can be modified in accordance with the demands made by changes in this environment. For Piaget, this kind of activity in the early years reveals the origins of intelligent behavior.

Initially, the world is undifferentiated for the child. At the end of this stage, objects and events in the world tend to take on some identity of their own. The most significant feature of the sensori-motor stage is the attainment of object permanence, i.e., the realization that an object still exists even if it cannot be perceived directly.

Pre-operational Stage (18 months to approx. 6 years). With the onset of language and symbolic functioning, children are capable of mentally representing objects and events. This can be observed in instances of deferred imitation, i.e., imitating a situation after some time has elapsed, and in children's symbolic play.

Two major characteristics of this stage are (1) thought based on perception and (2) egocentric thought. Young children are said to be percept-bound when their judgments are formed purely on the basis of what is seen. Such thought is essentially static and tied to the immediate situation. The egocentric nature of children's thought is manifested in their preoccupation with "me" or "I." There is no differentiation between internal and external environments or objective and subjective states, so that "me" and the world outside are all one and the same. It is difficult for children to co-ordinate other points of view into their thinking as well because they do not realize that others may think differently from them.

Concrete operational Stage (6 years to approx. 11

years). A profound re-orientation occurs at this stage because children are not bound by their perceptions alone. Their thinking is now transformative and reversible, i.e., they can perform changes, and move back and forth mentally. Instead of being tied to the immediate situation, they begin to make inferences about reality. However, children are still tied to the concrete rather than the abstract.

Characteristic operations that children can perform at this stage are classification, seriation and conservation. The major attainment is that of conservation which involves the realization that things remain invariant even after certain changes are made or occur.

Formal operational Stage (11 years oneward). This is the stage when true abstract thought develops. Possibilities can be conceived, hypotheses can be formulated and alternative strategies can be planned in the mind and in the absence of the actual event or situation.

The Relationship Between Children's Thinking and Their Questions About Causal Order

The kind of invarient relations that are most significant in interactions with the physical environment are those that deal with causal order. Understanding physical causality is of supreme importance in the life of the child, just as it is in the work of the scientist. Causal knowledge, from simple associative beliefs to the most sophisticated forms of causal dependence and interdependence, offers an assurance of control, security and practical application. Isaacs, in a book on <u>Children's Ways of Knowing</u>, emphasizes the fact that a knowledge of the causal structure of the world is indispensable to the growing child. He says that

> Behind most of the checks which the child's expectations or assumptions receive from the world, there are unknown or insufficiently known or misconstrued <u>causal</u> facts; the right kind of explanation will disclose these to him. Endless unexpected happenings, failures of expected happenings, deviations or differences from the customary, will turn out to be explained by unsuspected causes, by intervening or preventing causes, unknown determining or conditioning causes. Thus, causes and causal relations should come to be looked for as the important controls of what does or does not happen; and new or better causal knowledge, as the most potent means to true and successful expectation, and the key to secure and controlling knowledge of the course of things. Thus followed up, "causes" branch out into activating events on the one hand, controlling structures, compositions, natures, relations, etc., on the other hand. They become extended to include every kind of relevant or possibly relevant circumstances or conditions or facts of immediate or wider setting; everything which, if it were different, would make any given thing different. Carried right through, causal inquiry becomes, of course, eventually the basis for our most systematic and comprehensive investigation into the construction and controls, the general structure, of our world; in other words, the warp and woof of science. (1974:50)

The development of a critical attitude of mind is indispensable to the attainment of technological competence. Scientific method is a valuable tool in helping children to understand cause and effect relationships in the physical environment.

Since cause and effect relationships are formally expressed in the optimal formulations or laws and principles of natural science, it will be necessary to identify these laws and principles in a science curriculum. The science curriculum should be organized in such a manner that children at different developmental levels can understand the laws and principles.

The following chapter outlines some of the major laws and principles of natural science and gives examples of how they may be organized so that they are appropriate for children in different stages of development.

Isaacs places the child's desire to find out about causal events within the broader context of the types of questions that are asked concerning objects, events and people. The subject of children's "why" questions is analyzed thoroughly and an explanation is ventured as to why they occur so frequently at certain ages. Isaacs' thesis is that children have a genuine 'epistemic' concern about the state of their knowledge. Challenges to their systems of belief regarding reality present the sense that something is wrong with their knowledge--it may be some unsuspected error, confusion, insufficient information or misunderstanding. Children do not formulate or articulate this epistemic concern in a conscious manner, but they act it out by posing the "why" question.

"Why" questions do not always ask for a causal explanation. Because of their developing language ability children may frame a "why" question but really be seeking something other than an explanation. The multiple usages of "why" make it somewhat difficult to discern exactly what is being sought. However, if a satisfactory answer is not forthcoming, the unremitting "why" is bound to reappear.

Three basic types of "why" questions have been identified by Isaacs (1974). There are questions that seek information, explanation or logical justification.

Informational Questions

Essentially, these questions seek to inquire into motives, intentions, purposes, uses or functions. They are usually demands for familiar classes of information rather than explanation. These "why" questions are more closely allied to question forms such as "where," "when," "what," "who"--questions that arise out of simple ignorance or lack of knowledge and not from a state of puzzlement and helplessness. So when a child says "Why is this a cup?" the answer that is being sought is not an explanation but something that has to do with the differences between classes of objects such as cups, glasses, and mugs.

Explanatory Questions

This group of questions is derived from the initial informational questions but becomes limited to causal intervention or control or analysis. The real interest here is one of explanation which does involve a measure of information but this is of secondary importance. Information that is given is accepted if it really explains the observed anomaly or confusion. According to Isaacs this type of "why" question is unmistakable in children from about four years and onward. A sudden jar or onset of surprise creates a condition of disturbance and children may ask such questions as (from Isaacs):

> "When you hold up a fountain pen, why doesn't the ink fall out?"
>
> "Why don't we see two things with our two eyes?"
>
> "You aren't dead, so why don't you get up?"

Answers to these questions are not simple to explain to a child. Adults may provide an acceptable answer by some demonstration, identification of a rule or pointing out some distinction. However, it is evident that erroneous notions and superstitions can creep into the child's thought by the appropriateness and the truth-value of the answer.

Justificatory Questions

These questions are neither explanatory nor informational. They demand the grounds for rules, commands and prohibitions as they relate to behavior. Principles or reasons which presuppose some standard are sought--

these may be moral, social or conventional standards of individuals, families or of the society as a whole. Children who ask "Why do I have to do what you say?" are seeking what the basis of one's authority might be. The difference between these types of questions and the other two types is that an attitudinal or emotional factor may be involved which may or may not lead to a clash of views, rebuttal of ideas or disregard. Discussion and an exchange of ideas and beliefs are required when these "why" questions occur.

Children's understandings develop to a greater or lesser extent depending upon their experiences as they look for causal factors that control events. A greater voluntary interest develops in discovering causal relationships not only because it provides information but also because it fulfills the need to bridge the gaps in the child's knowledge that arise out of genuine puzzlement or contradiction in experience. Once developed and if it is successfully sustained, causal inquiry becomes an invaluable tool that can assist the child in learning to understand the laws and principles that govern the organization of the world of nature.

Development of Children's Understanding of Physical Causality

A child's developing notions of cause and effect relationships in the physical world appear to follow a pattern or sequence. Most of the systematic research has tended to focus on children aged three or four. Research on infants is not so extensive but it is possible to piece together a picture of the earliest form of causal orientation from isolated reports. Piaget's investigations into the sensori-motor stage of development are by far, in an indirect manner, the most comprehensive treatment of causal interest in very young children. The sequence of development begins with what may be termed "contingency awareness," followed by a stage of pre-causal thought and finally the period of true causal thinking.

Contingency Awareness

As early as a few weeks after birth, infants explore their environment both visually and physically. When they discover that one action leads invariably to another in a regular fashion, a rudimentary form of causal awareness begins to grow. Stern reports that at the age of three months, infants play with objects by touching, rolling, dropping or holding them and in these ways give themselves simple lessons in physics and geometry (in Huang, 1943). Gesell and Thompson found that infants of nine months of age engage in ceaseless manipulations and initiate the development of later understandings of physics (in Huang, 1943). In a string toy experiment, the authors found that infants would constantly pull the string to bring the toy within their reach.

Piaget's book on The Origins of Intelligence in Children (1952) is filled with numerous examples of children's developing notions of cause and effect relationships. In the early stage, when the child is about one-two months old, movements are usually centered on the child's body, e.g., sucking a thumb or hand, waving the arms or grasping other parts of the body such as a foot or a hand. During the next stage, called the "secondary circular reactions," (about three months) the child's actions tend towards repetition. After reproducing some of the results that were discovered by chance by actions on the body, the child then tries to repeat certain events in the external environment. The characteristics of this stage are that ". . . the movements are centered on a result produced in the external environment and the sole aim of the action is to maintain this result; furthermore it is more complex, the means beginning to be differentiated from the end, at least after the event" (Piaget, 1952:157).

During the secondary circular reactions stage children devote their energies to "procedures to make the interesting spectacle last." Piaget describes how his son, when given a paper knife, started shaking it so that the sound of a rattle (which he had played with previously) could be reproduced. In another example, his daughter would shake her foot or body to cause swinging--she had learned that this type of shaking could cause certain things, e.g., a bassinet, to rock or swing. However, when other objects such as a watch or eraser were just held above her, she would shake her feet to reproduce a previous interesting result. For Piaget, the activities of this stage are the "highest intellectual manifestations of which the child is capable" (1952:207). Later in the infant's development more deliberate exploration and simple experimentation can be witnessed.

Watson (1966) postulated the term "contingency awareness" to refer to any early form of causal association, when the only reward was the observation of the event. He played a game with his two-month old son. The contingent event was the opening and closing of a fist when the child looked at Watson's outstretched arms. When the child turned away the activity ceased, but when his gaze fell on the fist again the movement was repeated. Learning the contingency led to the repetition of the head-turning response. Further experiments conducted by Watson and Ramey (1972) utilized a contingency mobile which an infant could activate by means of a pressurized pillow. Eight week-old babies learned to turn their heads frequently so that the mobile would move. The authors were surprized to discover an emotional effect in that the infant's response was accompanied by cooing, smiling and laughing. The authors cite a cautionary note that the experiment may have over-stimulated the infants, which may have some disadvantageous consequences. However, an important implication of this experiment is that even very young infants find the detection of causal relationships satisfying and rewarding.

Pre-Causal and Causal Thinking

In a book on The Child's Conception of Physical Causality (1930), Piaget investigated the underlying cognitive structures that assist children in discovering cause and effect relationships. He utilized the clinical method of interviewing children by presenting questions and demonstrations on various natural phenomena such as air, clouds, water, shadows, dreams and machines. The answers that the children gave fell into seventeen types, the first nine of which were characteristic of pre-causal thought and the remaining eight of causal thought. According to Piaget, before the ages of seven or eight children's explanations of natural phenomena are basically magical, or animistic, i.e., a belief that the physical world of objects, plants and animals are endowed with life. True causal thinking appears at about seven or eight years of age but is not prevalent until eleven or twelve years of age. Explanations now begin to be logical and refer to physical laws and principles, and the earlier animistic explanations tend to disappear gradually.

Piaget states that the development of physical causality is characterized by two major processes: (1) the progressive objectification of causality and (2) the formation of temporal series.

The first process is related to the egocentric world of the child--subjective elements predominate. Precausal children do not make the following distinctions: between psychological or motivational factors and physical, external events because there is very little differentiation between the internal self and the outside world; between muscular or body activity and mechanical action; and between the influence of the mind on the body and the influence of external objects on each other. Because of the basic lack of differentiation between themselves and the external world, young children feel that they can make the moon follow them, or that the moon likes to follow, that objects float because they like to do so, that the clouds walk and the moon goes with them, or that clouds move because they feel cold.

The constitution of a temporal series is the second process that affects developing notions of causality. Very young children (3-6 years) are not concerned about how long it takes something to happen--events in their lives are either immediate or extra-temporal in nature. The sun or the moon follow as soon as the child begins to walk. Precausal children believe in the immediacy of events such that no thought is given to any intermediaries or contact between cause and effect relationships. Children of four or five years of age think that cars move only because of the wheels, whereas an eleven or twelve year old may not know all the details of operation of the car but will presuppose a system of belts, pipes and chains. Notions of before and after may be present in precausal children but it is the idea of a temporal order in time that is absent, e.g., beginning, middle and end or the fact that a particular tree is the same tree during summer, winter, fall and spring.

For Piaget, the stage of pre-causal thought is inexplicable unless some system of internal origin is postulated as an intermediary between the environment and the mind. The child begins without any distinction between the self and the environment, and gradually an awareness of the body as a separate entity develops. Piaget does not believe that causality develops as an a priori form, fixed in the structure of the mind, for if this were so, then causality should appear in its completed form at the outset. Also, the fact that causality evolves through so many types of explanations leads Piaget to the conclusion that an understanding of physical causality develops through interaction with the environment and that the child passes through stages of development of structures that are continually adapting to the environment and being modified by changes.

Criticism and Confirmation of the Pre-Causal Stage

Piaget's identification of the pre-causal stage as being characterized by magical and animistic forms of thought has not been accepted by many researchers in this field. Numerous studies have been conducted in the hope of confirming Piaget's views. The outcome has been mixed--there are just as many studies that confirm pre-causal thinking as there are studies that do not find any evidence for this early form of causal thought.

In a highly critical review of Piaget's work, Huang (1943) put forward the idea that children only sometimes explain natural phenomena in animistic terms. He studied American and Chinese children and found that pre-causal thought, especially mystical and anthropomorphic answers, were completely absent. Deutsche (1937) used some of Piaget's questions to which she added ten simple physical experiments, and discovered that children very rarely relied on precausal forms of explanation. Most explanations called upon physical or mechanical concepts. Certain cross-cultural studies have also pointed out that animistic explanations are not always prevalent--Mead with the Manus tribes on the Admiralty Islands and Jahoda with children in West Africa (in Laurendeau and Pinard, 1962).

On the face of this evidence it would seem that the existence of a precausal stage should be abandoned or rejected. However, there have been a series of investigations that have definitely confirmed the various types of precausal thought. Numerous studies by Russell and Dennis (1939) with children of normal intelligence, with American children and Zuni (Dennis and Russell, 1940) and with Hopi children (Dennis, 1943) substantiate Piaget's view.

The largest study supporting Piaget's results was carried out by Laurendeau and Pinard (1962). Using five hundred children between the ages of four and twelve, they reinvestigated whether precausal thinking existed. Animistic explanations occurred with such frequency that the existence of a qualitatively different form of thinking in young children could not be doubted.

These authors also caution the ready acceptance of the results of studies on physical causality. Factors such as the following should be carefully examined in the experimental situations: (1) methods of investigation, e.g., the use of certain types of questions, questioning techniques and questionnaire format; (2) types of subjects, especially as regards age (some researchers used a questionnaire with 8 year olds since they could read and did not find any precausal forms of thinking--this is not unusual since true causal thought begins to develop at about seven or eight years); and (3) techniques of analysis, particularly in the identification, classification and definition of the different forms of precausal thinking. Laurendeau and Pinard conclude that the reality of the existence of pre-causal thought is far from being definitely resolved since the evidence for its prevalence is so controversial.

Factors That Influence the Children's Understanding of Physical Causality

Even though the information on pre-causal thinking is not so clear-cut, the importance of children's developing notions of cause and effect relationships has been acknowledged, particularly in the role of assisting children to know the basic means by which the physical world functions. To overcome some of the methodological problems involved in the technique of investigation, various researchers have tried to identify the influence of relevant situational factors. Baldwin (1955) and Russell (1956) have suggested that children revert to non-naturalistic explanations when the phenomena that are being presented are unfamiliar. Children are therefore unable to explain the cause and effect relationship in a reasonable manner. Berzonsky's studies (1971, 1975) which represent the most recent research in physical causality, also support the fact that a child's familiarity with objects or events is a decisive factor in causal reasoning. The role of experience in causal thought is related to that of familiarity and has been shown to be necessary when trying to investigate a child's level of understanding of causal events (Mogar, 1960; Huang, 1943; Berzonsky, 1975; Inbody, 1963).

Researchers have also discovered that the psychological state of the child affects an understanding of physical causality. Berger et al. (1969) found that children with severe psychogenic learning inhibitions used developmentally less mature concepts than normal children when presented with physical events. Reasons advanced for this condition are that the disturbed parent-child relationship retards the initial development of causal concepts, or that parents unconsciously thwart the child's attempts to know and understand sequences of painful reality events, or that parents preferred to handle situations with the child by secrecy, deception and the distortion of reality. Nass (1956) found that the withdrawn child's level of causal thinking was at a significantly less mature level than a child who was not withdrawn. Children with withdrawal symptoms tend to find the environment threatening and retreat into their own world and thereby revert to prelogical modes of thought.

A close relationship exists between a child's understanding of physical causality and psychological causality (Whiteman, 1970) which has later implications for moral development. Kohlberg's work on moral reasoning and Selman's studies on social perspective-taking presuppose the development of physical causality especially in the progressive differentiation of the self and the external environment. Children learn to consider other people and their feelings when they realize that they themselves are separate entities.

Children's Application of Scientific Method

It would be safe to conclude from the foregoing discussion that the types of causal explanations that children present reflect their level of scientific thinking. The assumption is that the qualitative differences in the explanations at different stages of development are the external manifestations of an internal pattern of organization of thought processes. As was noted at the beginning of this chapter, the scientist's mode of thinking was inferred from the actions performed, i.e., scientific method. The processes of observation, hypothesis-formation, prediction, and theory formation have been well-documented in adult scientific thought. In the case of young children, the developmental progression of processes of scientific method have not been thoroughly and systematically investigated. However, some information is available from Piaget's experiments with physical phenomena (in Ginsburg and Opper, 1969).

A pendulum problem was presented to subjects in the pre-operational, concrete-operational and formal operational stages of development. The problem was to discover the frequency of oscillation of the pendulum in relation to four factors which could be manipulated--height of pendulum, length of string, weight of suspended object and force with which the pendulum could be pushed.

It is immediately evident that the problem is beyond the capability of a 6 or 7 year old child, but it does provide some insight into how the child might be thinking. The pre-operational child acted in a haphazard manner--testing was random, results were reported inaccurately and expectations influenced observations. However, the subjects did formulate hypotheses (even though they were inaccurate), made observations, experimented by attempting to manipulate variables and drew conclusions which were not in accordance with the results. The concrete-operational child showed a marked improvement--a number of variables were investigated, results were observed accurately and the solution to the problem was partially correct. The major deficiencies lay in poor experimental design (which could be expected because there were too many variables to manipulate) and incorrect inferences were drawn. Finally, the formal operational subjects (adolescents) design the experiment properly at first, then observe the results accurately and draw logical conclusions from the observations. Hypotheses were carefully formulated, variables were manipulated one at a time and the conclusions were "certain and necessary" (Ginsburg and Opper, 1969: 188).

Clearly the pre-operational child's scientific thinking is different from the adolescent's thought but only in a matter of degree. Not being capable of abstract thought, young children have difficulty in conceptualizing hypothetical combinations and mentally manipulating variables. The concrete operational child has the beginnings of abstract thought but is still tied to the concrete situation. As the child develops more complex cognitive structures, then true scientific thinking will gradually emerge.

The ability to think in a scientific manner can prove to be an invaluable tool for children, not only when they are young but throughout their lives. If children are introduced to the application of the scientific method when they are young, then they will have an opportunity to gradually develop a critical attitude of mind in relation to their experiences in the physical, human and unknown environments. One of the goals of education, according to Piaget, is "to form minds which can be critical, can verify, and not accept everything they are offered" (in Barber and Hayes, 1973:13).

A critical mind will go a long way in helping to free children (and adults) from error, superstition, prejudice, dogma and fear. Such beliefs, once established, have a tendency to persist in how people think, feel and behave in certain situations. The habitual patterned use of energies in these directions then become very difficult to eliminate. To avoid the harmful and destructive effects that can accrue from acting on the basis of superstition, error and fear, children should be encouraged, when young, to question, investigate and verify statements as much as possible. When errors are not detrimental to the life of a child, they can serve as valuable experiences in learning more about a particular event or phenomenon. Errors have the capacity to act as lures so that further hypotheses can be formulated to test out some problem and in this way a solution that is closer to the truth, i.e., a closer approximation to reality, can be achieved. The persistence of the search after truth is described by Whitehead when he claims that "It belongs to the self-respect of intellect to pursue every tangle of thought to its final unravelment" (1967c:185).

Situations will arise, more so with adolescents and adults, when information about certain things will be accepted even if all the facts are not known. Such instances occur when results are reported from certain fields of specialization or when experts give their advice and opinions. Does a person have to blindly accept what is heard or what is read, or is there some means by which the information can be assessed? There appear to be three checks that can be fruitfully applied. Firstly, the validity of the information will depend on the source of the information, e.g., was it read in a reputable journal, a not-so reputable newspaper, on television or from another individual? Secondly, the potential replicability or the actual number of replications of the results will have to be assessed. Hearing of an isolated instance of a cure for some disease does not lend authenticity or credibility to the information because one does not know whether the cure will be effective in other situations as well. Thirdly, the operation of different variables will have to be checked. If enough facts are available and there is a sufficient level of understanding of the information, then further examinations can be made. The three checks mentioned are all facets of a scientific mode of thinking. Dewey comments that science and its methods involve "an intelligent and persistent endeavor to revise current beliefs so as to weed out what is erroneous" (1966:19).

Whether children will try to check their ideas, readjust their beliefs or extend their knowledge depends to a large extent on the standard of explanation that adults present (Isaacs, 1974). Adults can encourage or discourage the child's explorations; they "can rebuff, confuse, mislead and stifle it in endless ways" (Isaacs, 1974:53). Isaacs concludes the section on children's "why" questions and the development of their scientific thinking by pointing out to adults that

> But these are the factors that will beyond anything else decide the general character and level of his intellectual life. They will determine the degree of control which actuality is allowed to exercise over his notions and beliefs. Nothing can be more fatal to growth in adequate knowledge, or in the capacity for objective judgment, than the vitiation of that actuality-control by a low social standard of explanation. If it sanctions explanation by pretentious tautologies, by arbitrary selections of partial causes, by imaginary and mythological causes; if it seems to authorize endless irrelevance, the divorce of explanation from its occasions and function, its confusion with verbal and formal self-justification (and the substitution of the latter for enquiries into evidence) and if, moreover, it does this all together in one anarchic medley--the result will be self-evident. Such a social standard must continually tend to blunt alertness; to confuse the functioning of such native functional standards as we may possess; to discourage an interest which it hinders or leads astray from achievement; and in general, to make us drift towards a state of chaotic muddle-mindedness which then in turn can only, in a vicious circle, reproduce itself. By continuous efforts to counteract its consequences, impelled and sustained from the one direction in which we have achieved successful integrative growth, i.e., science, and the scientific attitude and method, we may indeed keep them under control and even very slowly and laboriously gain a little upon them. But at the very best, the most part of the work of our special socially delegated organ of cognitive growth must thus be wasted, so long as we are content with a general social and educational standard of explanation which lags so far behind that which science itself has reached, and which is the basis for all its achievement. (1974:52-53)

The next chapter will outline the framework for a natural science curriculum within the context of the overall curriculum. This framework will form the basis from which developmentally-sequenced science concepts and activities could be elaborated in greater detail.

CHAPTER V

PROPOSED FRAMEWORK FOR A NATURAL SCIENCE CURRICULUM BASED ON AN ORGANISMIC APPROACH

From an organismic perspective, the natural science curriculum should reflect the characteristics of wholeness, integration and relatedness. It is important then that these organismic characteristics be incorporated in the organizational format of the natural science curriculum.

This chapter will outline one possible logical structuring of the framework of the natural science curriculum rather than a developmentally-based structure. The reason for presenting the logical scheme first is that it can provide a base from which developmentally-sequenced science curriculum goals can be planned and implemented. Developmental information on the nature of children's scientific thinking is vital if such curriculum goals are to be outlined and executed (see Chapter IV). Chapter VI will present prototypical sequences of developmentally-based science curriculum goals.

Before discussing the logical structure of the framework of the natural science curriculum in the Anisa Model, it will be useful to understand the nature of curriculum in general. To provide the context for this discussion, the Anisa Theory of Curriculum will be presented and its relationship to the framework for a natural science curriculum will then be explored.

The Anisa Theory of Curriculum

In the Anisa Model, curriculum is defined as being "comprised of two interrelated sets of educational goals and what children do, usually with the help of peers and adults to achieve these goals" (Jordan and Streets, 1973:30).[1] The two sets of goals are: process goals and content goals. Process goals refer to the "hows" of learning and depend on the classification of a person's potentialities and how they become actualized. Content goals refer to the information to be learned by the person. The organization of the information (content) to be learned is congruent with the classification of the environments according to Whitehead's ontological levels (physical, human and unknown) and upon the formation and utilization of basic symbol systems (mathematics, language and the arts) to convey the information. What children do (the interaction component) represents those activities that children engage in to attain the goals of the curriculum.

Process and content goals, specific formation and utilization of symbols, and types of interactions are all

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[1]A further exposition of the Anisa Theory of Curriculum will be presented by Lawrence McCullough in a forthcoming dissertation.

determined by the overarching purpose of the higher-order competencies, i.e., technological, moral and fiducial competencies. The interrelated components of the Anisa Theory of Curriculum, which are organized around the higher-order competencies, may be outlined as follows:

I. Process goals

II. Content goals

III. Formation and utilization of symbols

IV. Interaction with particular environments to achieve the goals.

Components of the Anisa Theory of Curriculum

A description of the components of the Anisa Theory of Curriculum will help to make clear their role in the framework that is being proposed for the natural science curriculum. The specificity of the process and content goals, symbol formation and utilization, and particular activities is determined by the higher-order competencies.

I. Process Goals

Five basic categories of potentialities have been identified in the Anisa Model: psychomotor (moving), perceptual (perceiving), cognitive (thinking), affective (feeling), and volitional (willing) potentialities. The internalization of processes underlying each category of potentiality results in the attainment of learning competence in that category. There are numerous processes underlying each category which have to be mastered if learning competence is to be achieved.

Since the notion of process is central in organismic philosophy and so crucial in the Anisa Theory of Curriculum, it will be useful to understand the way in which the word is being used. Jordan defines process in the following manner:

> We use the word process to refer to the functioning that is made possible by some structure in the brain which is built up out of the organism's particular interactions with particular environments. Process is not to be confused with activity that is provided for the child. We reserve the phrase interaction with the environment to describe what the child does. It is the purpose of the process curriculum to specify what kinds of environments and what kinds of interactions with those environments are necessary for particular structures to emerge, thereby endowing the child with competence to function in terms of their associated processes. (Jordan, 1976:277)

The process goals then are concerned with the "how" of learning as opposed to the "what" of the content curriculum. Children gradually learn how to move, how to perceive, how to think, how to feel and how to formulate goals and execute them. The basic processes in each category of potentiality assist children in learning how to learn, thereby becoming competent learners.

Learning competence has been defined as the conscious ability to differentiate aspects of experience (psychomotor, perceptual, cognitive, affective and volitional experiences) and to integrate these aspects into a pattern in some new way and then generalize the integrated pattern to other similar situations. The word "conscious" has been used to refer to knowing that one knows rather than just knowing something without being aware of it. Human beings employ symbols to represent what they do know and the state of not knowing something. Learning competence therefore depends on the conscious ability to use symbols to differentiate, integrate and generalize aspects of experience.

The attainment of learning competence in each category of potentiality will result in the achievement of psychomotor, perceptual, cognitive, affective and volitional competencies. Each competency will depend on the conscious ability to differentiate, integrate and generalize aspects of experience related to a particular category. The five basic competencies are very closely related and will be implicated in each interaction with the environment.

II. Content Goals

The content of the curriculum depends on the information to be learned. There are two basic types of information: (1) descriptive information which includes basic factual information, and (2) more formalized information that can be generalized to different situations. The information to be learned is organized according to the ontological levels of the universe as described by White-head.

III. Formation and Utilization of Symbols

The information that is to be conveyed will be coded in symbols, i.e., mathematical symbols, language symbols and the symbols of the arts. Depending upon the purpose that the individual has in mind, different symbolic forms will be utilized.

IV. Interaction with Particular Environments to Achieve the Goals

One of the basic propositions of the Anisa Theory of Development is that development is sustained through interaction with the environment. Children's interactions with the environment will be organized in such a manner so that the goals of the curriculum can be achieved. The particular environments to be interacted with will be determined by (1) the information to be learned, (2) the process goals to be achieved, and (3) the developmental level of the child. Activities that are organized for children will incorporate the fusion of process and content goals, foster the development of symbolic capacities and the formation of values and the higher order competencies so that the act of learning is an integrated, holistic experience.

As the child interacts with the physical, human and unknown environments, material, social and philosophical values are formed respectively. On each of these values rests the attainment of technological, moral and fiducial competence, respectively (see Chapter III). This dissertation deals only with the presentation of a possible framework for a natural science curriculum, the goal of which is the attainment of technological competence.

Components of the Natural Science Curriculum in Accordance With the Anisa Theory of Curriculum

The interrelated components of the natural science curriculum will be organized around the overarching purpose of achieving technological competence. These components are:

I. Process goals

II. Content goals

III. Formation and utilization of symbols, primarily mathematics and discursive language

IV. Interactions to achieve the goals

I. Process Goals

Each of the five basic competencies will be implicated in each interaction with the physical environment.

A. Psychomotor competence will depend on the conscious ability to use voluntary muscles in locomotion and in manipulation, particularly fine motor skills for handling specimens and instruments.

B. Perceptual competence will depend on the conscious ability to process sensory data from the environment, i.e., visual, tactile, olfactory, auditory and gustatory information. The foundation of natural science rests upon careful and detailed observation.

C. Cognitive competence which is crucial in science depends on the development of the intellectual processes that can be consciously used for thinking and reasoning. Processes of scientific method such as observation, hypothesis formation, experimentation, deduction, induction, prediction and inference are vital in helping children discover the relationships between physical events. Other processes such as classification, seriation and conservation are also important, particularly in the understanding of quantitative relationships.

D. Affective competence will depend on the conscious organization of emotions so that viability can be accurately assessed. Emotions that relate to hope and fear affect the release of potential. Hope-related emotions lead to active involvement and enjoyment, whereas fear-related emotions lead to avoidance reactions and anxiety. To avoid the development of superstition, it is important that the hope-related emotions become associated with the principles and methods of science which are designed to discover error in belief and so generate new knowledge.

E. Volitional competence depends on the conscious ability to attend to some aspect of experience, formulate goals and persevere in the attainment of these goals. The great discoveries in science are made by scientists who toil laboriously over many years to achieve their goals. Without volitional competence, the need to do things over and over again cannot be met.

Even though each of the competencies has been separated for the sake of analysis and discussion, it must be remembered that all of the competencies are implicated in each interaction with the physical environment.

II. Content Goals

In the natural science curriculum the content to be learned is the knowledge or information that has been accumulated about the physical environment. The information to be learned is of two basic types: (1) descriptive information, i.e., basic facts and definitions; and (2) abstract, generalizable information such as the basic laws and principles of natural science, which express fundamental patterns of relationships in the physical world. With the onset of more abstract thought processes, these laws and principles can be learned and generalized to other similar situations. A detailed outline and description of the two types of information will be presented in this chapter.

III. Formation and Utilization of Symbols

A statement on the role of symbolization in natural science was presented in Chapter III. Mathematics and discursive language are used primarily by scientists to convey information about the physical environment. Music, visual art, dance and poetic and dramatic uses of language contribute to the development of sensitivity to, and appreciation of, forms, patterns and harmony in nature. Metaphor and analogy are often the means of new discoveries in the sciences.

IV. Interaction to Achieve the Goals

What children do to achieve the goals of the natural science curriculum will depend on the kinds of learning experiences that are planned. Experiences will be organized to impart information and understanding about the major laws and principles of natural science (content goals) and to strengthen the processes underlying the basic competencies (process goals).

To make natural science an exciting and challenging experience for children, the activities that are planned should be organismic in nature and relate to the lives of children, to real problems that may be encountered, and to their developmental levels.

The overarching objective of the natural science curriculum is the development of technological competence in interacting with the physical environment, i.e., the development of the conscious ability to understand, discover and apply the laws and principles of natural science in such a manner that greater control over the physical environment can be exercised.

Process Goals of the Natural Science Curriculum

There are many basic processes that must be internalized if technological competence is to be attained in interacting with the physical environment. The following brief list identifies some of these basic processes that constitute the process part of the natural science curriculum (for definitions of each process see Jordan [1976]). This is not an exhaustive list and is presented here to give examples of the kind of processes involved.

<u>Psychomotor processes</u>: balance/posture, locomotion, manipulation, vocalization.

<u>Perceptual processes</u>: visual, auditory, olfactory, taste, tactile, intersensory integration.

<u>Cognitive processes</u>: object permanence, deduction, induction (includes observation, prediction, experimentation), extrapolation, interpolation, classification, seriation, conservation, number relations.

<u>Affective processes</u>:	evaluative (reflection, appraisal), regulative (facilitation, inhibition, coping), empathic (imitation, identification, reciprocation).
<u>Volitional processes</u>:	attention, goal setting, will (self arousal, perseverance, effecting closure).

Science activities that are planned for children can foster the internalization of many of these basic processes to a greater or lesser extent. For example, a simple experiment on the expansion of metals will implicate processes from each category of potentiality: processes of manipulation in the handling of materials (psychomotor), visual processes of observation (perceptual), thought processes such as classification, seriation, conservation, prediction, hypothesis-formation, experimentation (cognitive), evaluative and regulative processes involved in enjoying and coping with the task (affective), and finally, persevering in the achievement of the goal (volitional).

It is evident that the cognitive processes play a crucial role in the natural science curriculum, largely because of the need for the development and refinement of the intellectual processes that are necessary for thinking and reasoning. The particular expression of the cognitive processes will be realized in the fusion with the content part of the natural science curriculum. A detailed outline of the content goals will be presented in this chapter.

A unique feature of the natural science curriculum is that the cognitive processes that are stressed in the natural science curriculum are also a part of other curricula, e.g., the cognitive development curriculum, moral development curriculum, social science curriculum. From an organismic point of view, such interrelationships are inescapable and necessary.

Two examples will assist in clarifying the concept of horizontal transfer of processes across various disciplines. The process of seriation, i.e., arranging things in terms of ordered differences, can be applied to animals and plants (largest to smallest), to people (tall to short, happy to sad) and to ideas or goals (most significant or important to the least significant or important). Prediction (inference) is a cognitive process that can be applied in a specific manner to investigating whether it will rain or not given the prevailing weather conditions, or else a prediction can be made about a person's general pattern of behavior given certain information about personality, age, and life experiences.

Being able to generalize processes from one area of knowledge to another is one of the most outstanding features of a competent learner. Understanding and applying the basic processes involved in scientific methodology will assist in the attainment of technological competence.

Content Goals of the Natural Science Curriculum

From the definition of technological competence which was presented in Chapter III, it is possible to determine the particular information that should form the content part of the natural science curriculum. Since the patterns of relationships between and among events were identified as being the keys to understanding the operation of the physical environment, then it becomes clear that these patterns should be systematically described and organized. The numerous patterns of relationships are summarized in the fundamental laws and principles of natural science. If one of the goals of a natural science curriculum is to impart this information, then a system of categories or a classification scheme needs to be established for the ease of learning and remembering the laws and principles.

Proposed Classification Scheme for the Fundamental Laws and Principles for a Natural Science Curriculum

I have found that having a definition of a law or principle can provide a basis upon which the major laws and principles of natural science may be classified. A law or principle is a statement about the organization, storage, transfer, utilization or transformation of energy that occurs during events in the physical environment. It should be emphasized that all events in the universe are ultimately understood in terms of energy. Even the concept of matter can really only be comprehended if we view matter as organized energy configurations. However, in the classification scheme that I am setting forth, matter will be viewed as one type of energy configuration so that events such as the interaction between matter and energy or the transformation of matter or energy can be considered.

Laws and principles that relate to the organization of matter, the storage of energy in matter and the transfer of energy between matter may be grouped together to form the study of physics. The interrelationship or interaction between energy and matter, rather than structural changes in matter, is usually examined in physics (except, of course, in atomic physics, where the boundary between physics and chemistry is less distinct and changes in matter are studied).

Laws and principles that concern the organization of matter, the storage of energy, and the transformation of matter from one form to another constitute the study of chemistry. The interaction between matter and energy results in a structural change in matter with the accompanying release or absorption of energy.

Laws and principles that involve statements about a living organism's capacity to utilize and store energy by transforming matter or energy from one form to another comprise the study of biology. The energy which is obtained by the living organism is utilized to support and maintain the vital life functions. This definition of the study of biology in physico-chemical terms is not meant to be taken in an extreme reductionistic sense. Some of the basic functions of living organisms may be analyzed in terms of physico-chemical reactions, but there are other characteristics such as life, integration and wholeness that are unique to living organisms and which cannot be analyzed in such terms (see Chapter II).

The study of physics and chemistry may be combined into the more inclusive group of physical sciences (i.e., non-living aspects of the physical world). Biology, which is a study of living organisms, may be viewed as life sciences. Physical sciences and life sciences may be combined to form the larger category of basic theoretical sciences.

A distinction is being made in this framework between the basic theoretical sciences (physics, chemistry and biology) and the integrative theoretical sciences (astronomy, geology, ecology). In the integrative theoretical sciences aspects of the physical environment are studied by using the laws and principles of physics, chemistry and biology. In astronomy, the laws and principles of physics and chemistry are studied as they relate to the celestial bodies, their composition, motions and evolution. In geology, the laws and principles of physics and chemistry are studied as they relate to the solid earth (internal and external processes) and the atmosphere of the earth. In ecology, the laws and principles of biology, physics and chemistry are investigated as they relate to the interactions between the living and non-living parts of the physical environment. Ecology may really be viewed as the most integrated theoretical science since it incorporates the laws and principles of physics, chemistry, geology and astronomy.

The distinctions between the various sciences are only made for the ease of classification and study. In contemporary natural science some events in the physical environment have to be analyzed from more than one perspective to be understood, and the need for real integration of knowledge is becoming apparent. For this reason many interdisciplinary fields have become necessary to develop a more complete understanding of relationships among phenomena in the physical world. Some of these fields are biophysics, biochemistry, molecular biology, physical chemistry, physical geology or geophysics, and astrophysics.

Figure II presents a possible schematic outline of the various categories of laws and principles proposed for the natural science curriculum.

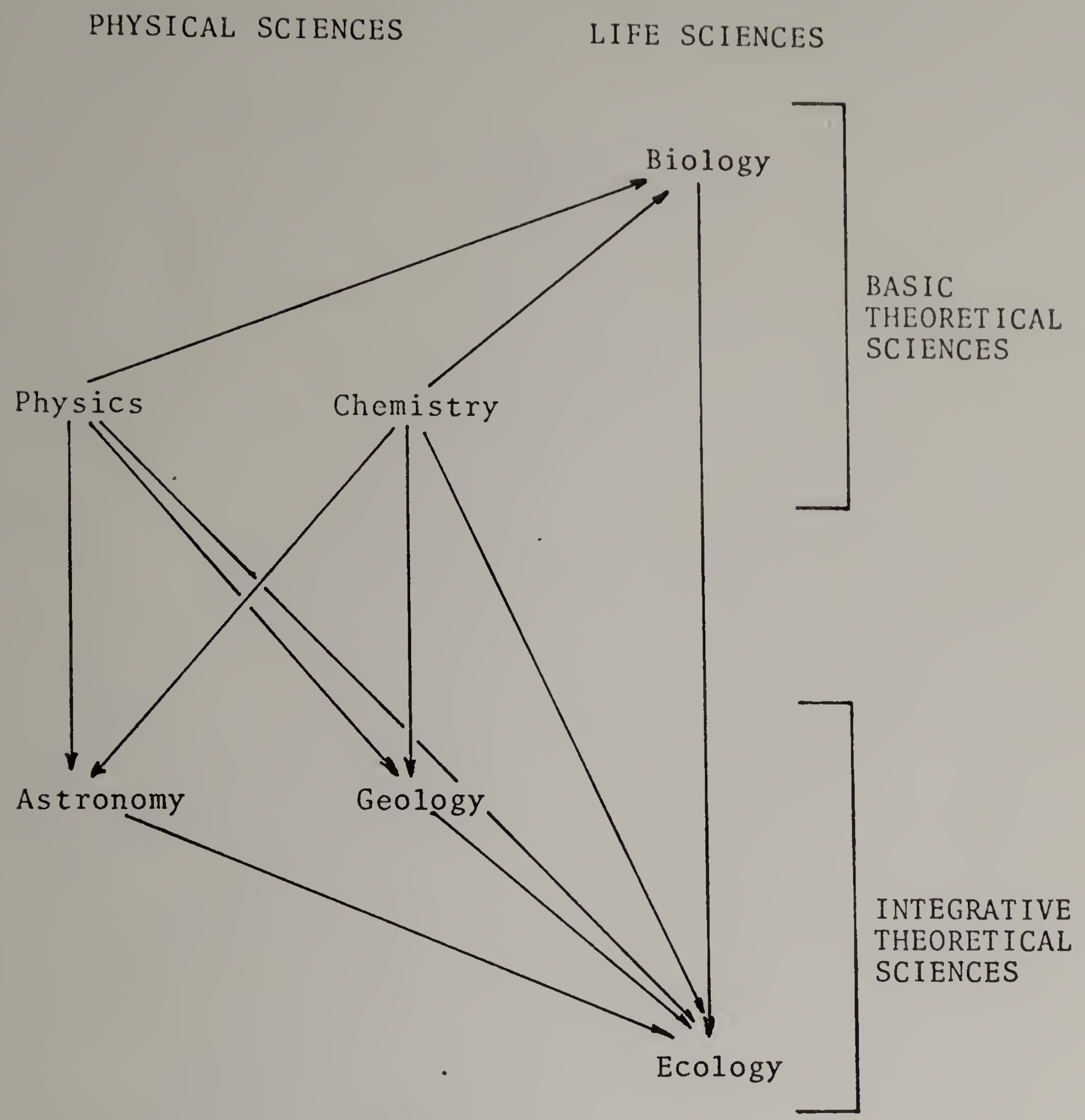

Figure II: A Possible Schematic Representation of the Interrelationships Between the Categories of Laws and Principles.

Outline of the Classification Scheme of the Fundamental Laws and Principles for a Natural Science Curriculum

BASIC THEORETICAL SCIENCES

PHYSICAL SCIENCES

I. PHYSICS

A. Organization of Matter
B. Motion and Force
C. Motion and Work
D. Types of Force
E. Types of Motion

II. CHEMISTRY

A. Composition of Matter
B. Chemical Dynamics
    1. Transformation of Solids in Liquids
    2. Transformation of Liquids in Liquids
    3. Chemical Reactions
    4. Thermochemistry
    5. Electrochemistry

LIFE SCIENCES

III. BIOLOGY

A. Functional Requirements
    1. Life-supporting and Growth Functions
    2. Interactive and Integrative Functions
    3. Perpetuation of Life Functions
B. Structural Principles and Diversity
    1. Structural Hierarchies
    2. Patterns of Structural Diversity

INTEGRATIVE THEORETICAL SCIENCES

PHYSICAL SCIENCES

IV. ASTRONOMY

A. The Solar System
B. Stellar Composition and Evolution
C. Galaxies

V. GEOLOGY

A. The Solid Earth
B. The Atmosphere of the Earth

LIFE SCIENCES

VI. ECOLOGY

A. Ecosystem Ecology
B. Population Ecology
C. Community Ecology
D. Habitat Analysis

Detailed Description of the Classification of the Fundamental Laws and Principles for a Natural Science Curriculum

The laws and principles in this section are stated in an abstract and complex form (particularly in physics, chemistry and astronomy) and will need to be modified in specific ways for teachers and for children, i.e., making them simpler and less abstract. Developmental information about specific children being taught a given law or principle will be vital in modifying the laws and principles so that the concepts will be appropriate to their developmental levels. Children at the pre-operational stage of development, for example, will require vastly simpler concepts than those at the early formal operational stage.

The following scheme is organized on logical grounds and not on developmental grounds. When this scheme is used in planning learning experiences for particular children, their developmental levels have to be assessed in terms of the processes that were outlined in the process component of the natural science curriculum. This assessment will enable the teacher to make the appropriate modification or simplification in the scientific law or principle being taught.

Together with the statement of each law and principle are certain definitions (or descriptive content information) which should be understood if the law or principle is to be learned. The definitions are not an exhaustive listing at this point in time, but such a listing will become necessary as the framework is worked out more fully.

Many of the laws and principles include mathematical concepts. Rather than outline all the prerequisite mathematical experiences, I have presupposed a certain level of mathematical understanding appropriate to each category.

BASIC THEORETICAL SCIENCES

PHYSICAL SCIENCES

I. PHYSICS

A. Organization of Matter

Certain types of energy configurations may be identified as varying states of matter.

Definitions: organization, matter (solids, liquids, gases), states, energy configurations.

B. Motion and Force

1. Newton's First Law of Motion (or Law of Inertia)
"A body remains at rest, or if already in motion, remains in uniform motion with constant speed in a straight line, unless it is acted on by an unbalanced external force"

(Asimov, 1966:24).
or:
if any change in motion occurs it is due to some force.

Definitions: motion, force, speed or velocity, friction, length, time.

2. Newton's Second Law of Motion
"The accelleration produced by a force acting on a body is directly proportional to the magnitude of the force and inversely proportional to the mass of the body" (Asimov, 1966:31).
or:
force is equal to the product of mass and acceleration (F=ma).

Definitions: acceleration, mass, proportion.

3. Newton's Third Law of Motion (or Action and Reaction Law)
"When two objects interact, the force exerted by the first on the second (the action) is equal in magnitude and opposite in direction to the force exerted by the second on the first (the reaction)" (Constant, 1963:110).
or:
for every action there is an equal and opposite reaction.

Definitions: interaction, action, reaction, equal, opposite, pressure.

C. Motion and Work

1. Principle of Kinetic Energy
When particles are in motion they possess a form of energy called kinetic energy.

Definitions: energy, heat, temperature, potential energy, chemical energy.

a. Heat and Solids
When solids are heated they expand and when cooled they contract.

Definitions: expansion, contraction, boiling point, melting point.

b. Heat and Liquids
When liquids are heated they evaporate and when cooled they condense.

Definitions: evaporation, condensation.

c. Heat and Gases
Charles' (or Gay-Lussac's) Law
The volume of a gas expands when heated and decreases when cooled.

2. Law of Conservation of Energy (or First Law of Thermodynamics)
Energy may be transformed from one form to another, but it cannot be created or destroyed.
or:
The total energy content of a closed system is constant.

Definitions: conservation, closed system, work (simple machines transform small force into a large force).

D. <u>Types of Force</u>

1. Force and States of Matter

a. Force and Solids
Hooke's Law
Strain is proportional to stress, i.e., objects undergo some deformation as a result of a force.

Definitions: stress (deforming force), strain (deformation caused by stress), elasticity, limit of strain.

b. Force and Liquids
Archimedes Principle (Principle of Buoyancy)
A solid body less dense than the fluid that surrounds it will float when the volume (weight) of the fluid it displaces is equal to its own original volume (weight).
or:
The upward force of liquids against submerged objects makes objects float.

Definitions: density, buoyancy, float, sink, volume, force, weight.

Water particles are held closely together by very strong forces (cohesion).

Definitions: cohesion, adhesion, surface tension, miniscus, capillary action.

c. Force and Gases
Boyle's Law
The pressure of a gas varies inversely with the volume, that is, if the volume increases the pressure decreases and vice versa.

Definitions: pressure, volume, increase, decrease.

2. Gravity

Newton's Law of Universal Gravitation
"Between any two objects in the world there exists a mutual force of attraction that is directly proportional to the product of the masses of the objects and inversely proportional to the square of their distances apart" ($F = Gm_1m_2/d^2$)(Constant, 1963:131).
or:
Every body in the universe attracts every other body with a particular force. (Specialized instance is the law of gravity: all objects close to the earth are attracted to the earth.)

Definitions: gravitation or gravity, weight.

3. Electricity

Coloumb's Law of Electrostatic Force
"Bodies with like charges repel and with unlike charges attract one another; for point charges (or small charged spheres) the force of interaction is proportional to the product of the charges and inversely proportional to the square of their distances apart" ($F = kq^1q^2/r^2$)(Constant, 1963:201).
or:
Bodies with like charges repel each other with a certain force and unlike charges attract each other with a certain force depending on the distance of separation.

Definitions: electrostatic, electric charge, like, unlike, electric current, electric circuit.

4. Magnetism

Coulomb's Law of Magnetic Force (early statement)
"Like poles repel, unlike poles attract, the force being proportional to the product of the pole strengths and inversely proportional to the square of their distance of separation" (F = const. $(m_1 m_2/d^2)$(Constant, 1963:225).
or:
Like poles of a magnet repel and unlike poles attract depending on the distance of separation of the poles.

Definitions: magnet, attract, repel, poles.

5. Electromagnetism

a. Ampere's Law of Magnetic Force (more recent statement in terms of electricity and magnetism)
The magnetic force is attractive when currents run in the same direction and repulsive when the currents are opposite, and the magnitude of the force is proportional to the product of the currents and inversely proportional to their distance apart.
or:
Electric currents can produce a magnetic field or force.

Definitions: field, magnetic field.

b. Faraday's Law of Electromagnetic Induction
Magnetic fields can produce electric currents by induction.

Definitions: induction (causing an electromotive force).

E. <u>Types of Motion</u>

1. Simple Harmonic Motion

Some bodies vibrate through alternate movement in opposite directions through the action of an elastic restoring force.

Definitions: vibration, alternate, opposite, restoring force, elastic, harmonic, music.

2. Wave Motion

a. Huygen's Principle of Wave Propogation
A wave is a disturbance that is propagated through space and/or a medium of some kind.

Definitions: mechanical waves (waves in which material particles are displaced, e.g., sound waves and water waves).

Electromagnetic waves (waves that are propagated in space, e.g., light).

Sound is created by mechanical waves which we hear and interpret as sound.

Light is made up of electromagnetic waves which we see and interpret as light.

Other electromagnetic waves: radio, television, infrared, ultraviolet, x-rays.

b. Law of Reflection
When a wave encounters a new medium, the wave is bounced off the medium in such a way that the angle made by the incident ray is equal to the angle made by the reflected ray.

Definitions: medium, angle, incident ray, reflection, reflected ray.

c. Snell's Law of Refraction
When a wave encounters a new medium and can pass through it, the speed of the ray changes.

Definitions: refraction, color, spectrum.

(NOTE: Relativity (principle of relativity) and Atomic Physics (quantum principle and Pauli's exclusion principle) involve complex concepts and will not be included here.)

II. CHEMISTRY

A. Composition of Matter

Matter is made up of small particles which are held together by bonds.

Definitions: particles, atoms, molecules, bonds. (Details on atomic structure will not be introduced until the formal operational stage.)

B. Chemical Dynamics

Matter can be transformed or changed by chemical reactions.

Definitions: chemical, dynamics, transformed, chemical reaction.

1. Transformation of a Solid in a Liquid

Solids may dissolve in a liquid to form a solution when the bonds holding the solid together are broken by the liquid particles.

Definitions: solution, dissolve, diffusion, saturation, supersaturation, crystallization.

Solids may be scattered as fine particles in a liquid if they do not dissolve.

Definitions: suspension, emulsion, colloid, gel, sol, protoplasm.

2. Transformation of Liquids in Liquids

One liquid may dissolve completely in another liquid (miscible).

Definition: miscible.

3. Chemical Reactions

a. Law of Mass Action
At constant temperature the rate of reaction is proportional to the active masses or amounts of each of the reactants.
or:
A chemical reaction depends on the amounts of reactants that are present.

Definitions: chemical, reaction, reactant, product, rate of reaction.

b. Reversible Reactions
A chemical reaction that can proceed in two directions (forward and backward) is reversible.

Definitions: reversible, forward, backward, equilibrium.

4. Thermochemistry or Heat and Matter

When matter undergoes a chemical reaction, it is transformed and heat is either absorbed or released.

Definitions: heat, absorbed, released, heat of combustion, heat of neutralization, heat of solution, cooking.

5. Electrochemistry or Electricity and Matter

Certain substances conduct electricity when they are dissolved in a liquid.

Definitions: electrolyte, acids, bases and salts, indicators, neutralization, batteries.

(NOTE: A large part of chemistry will be included in biology as biochemistry and in physics as physical chemistry.)

LIFE SCIENCES

III. <u>BIOLOGY</u>

A. <u>Functional Requirements</u>

1. Life Supporting and Growth Functions

a. Energy Production and Related Functions
Living organisms must obtain energy to maintain life.

i. Nutrient Procurement
Living organisms must either take in or manufacture nutrients to obtain energy for the maintenance of life.

Plants take in raw materials (water, gases, light, minerals) to manufacture nutrients.

Animals ingest manufactured nutrients.

Definitions: nutrients, living organisms, energy, gases, light, minerals.

ii. Nutrient Manufacture
Plants synthesize their own nutrients through the utilization of solar energy or light and basic raw materials (photosynthesis).

Definitions: photosynthesis, solar energy.

iii. Nutrient Processing
Living organisms must process nutrients into a simpler form so that they can be utilized to obtain energy for building new materials.

Plants utilize the manufactured nutrients as they are in a simple form already.

Animals have to digest the complex nutrients which are taken in into simpler forms so that they can be utilized.

Definitions: processing, digestion, enzyme action.

iv. Transportation of Nutrients
Living organisms must transport nutrients in a simplified form to each part of the organism where they can be utilized.

Plants transport water and manufactured nutrients throughout the plant system (translocation).

Animals transport necessary gases and simplified nutrients throughout their bodies by the process of circulation.

Definitions: translocation, phloem, xylem, circulation, blood, heart, blood vessels.

v. Energy Production in the Cell (Cellular Respiration)
Living organisms must utilize (oxidize

and reduce) the simplified nutrients in the cell to produce energy which can maintain the functions of life.

Definitions: oxidize, reduce, cellular respiration, cell.

vi. Removal of Unwanted Material
Living organisms must remove unwanted material which may be harmful to the maintenance of life functions.

Plants mainly remove excess water (transpiration) and gases at certain times. Solid waste products are stored in certain parts of the plant.

Animals remove solid and liquid waste products (excretion) and gaseous by-products.

Definitions: transpiration, excretion, waste and by-products, kidney action.

b. Structural Support Functions
Living organisms must support their structures in the best possible manner so that the functions of life may progress.

Plants possess specialized thickened cells that function to hold the plant in a position where the maximum amount of sunlight may be obtained.

Animals may possess specialized hardened cells which support the body of the organism in the best possible manner.

Definitions: structural support, specialized cells, skeleton, cellulose, bone, cartilage.

c. Protective Functions
Living organisms must protect their more delicate structures from environmental influences so that the functions of life may be maintained.

Plants need specialized outer cells that protect and cover the delicate internal structures.

Animals possess a variety of specialized outer cells that protect and cover the delicate internal bodily structures.

Definitions: protection, internal, external, cellulose, cell walls, skin, scales, feathers, fur.

2. Interactive and Integrative Functions

Living organisms must interact with the environment and coordinate the functioning of their systems in relation to environmental stimuli if life is to be maintained.

a. Chemical Coordination
Living organisms need an internal system of chemical coordination to integrate their growth and activity in response to stimuli from the environment.

Plants integrate their growth and activity through plant hormones (tropisms).

Animals utilize chemical hormones as one means of integrating the various activities of their bodies.

Definitions: interaction, integration, hormones, chemical coordination, tropisms, taxes, endocrine system.

b. Nervous Coordination
Animals only possess a nervous system to coordinate the activities of their bodies in relation to environmental stimuli.

i. Sensory Input
Animals may possess a system of sensory receptors which receive and transmit information about the environment.

Definitions: sensory receptors, information, vision, audition, touch, taste, smell.

ii. Internal Coordination
Animals possess an internal system of nerves which transmit information from the external environment.

Higher animals possess a complex system of nerves which transmit information to the brain where interpretation takes place.

Definitions: nerves, transmission of information, brain, spinal cord.

iii. Neuro-Muscular Coordination
Animals respond to stimuli from the environment through neuro-muscular coordination.

Definitions: neuro-muscular, muscles, muscle action, effectors.

c. Patterns of Behavior
Animals interact with and adapt to the environment through various patterns of action.

Animals may achieve mastery in their interactions with the environment through learning.

Definitions: behavior, adaptation, mastery, learning, biologic clocks and circadian rhythm, hibernation, migration, communication.

3. Perpetuation of Life Functions

a. Reproduction
Living organisms need to produce offspring so that the species may be perpetuated.

Animals and plants produce offspring through asexual or sexual means. Variation in characters results from sexual reproduction.

Definitions: reproduction, perpetuation, offspring, asexual, sexual, pollination, fertilization, gametes, zygote, male, female.

b. Growth and Development
Living organisms need to produce offspring which can grow and develop through various stages till they reach full maturity so that they can also reproduce.

Definitions: germination, embryogenesis, metamorphosis, growth, development, maturation, life cycles.

c. Heredity
Living organisms transmit characteristics from parent to offspring via the genes in the chromosomes.

Definitions: heredity, parent, genes, chromosomes, mitosis, meiosis, somatic cells, sex cells, spermatogenesis, oogenesis.

i. Patterns of Inheritance
Living organisms follow certain patterns of inheritance in the transmission of characteristics from parents to offspring.

Mendel's First Law of Segregation: Genes exist in pairs and in the formation of gametes, each gene separates from its partner and passes into a different gamete so that each gamete has one and only one of each kind of gene.

Mendel's Second Law of Independent Assortment: Members of one pair of genes separate during meiosis independently of other pairs of genes and come to be combined at random in the gamete.

Definitions: inherited and acquired characteristics, recombination, variation.

d. Evolution
Living organisms have evolved into their present form over billions of years.

i. Law of Natural Selection: In the struggle for survival only the organisms with the most successful variations survive and are selected to transmit their characteristics to offspring.

The variations in living organisms are introduced by mutations and through the recombination of characters during sexual reproduction.

Definitions: variation, evolution, ancestor, survival, mutation.

ii. Adaptive Radiation
Living organisms have evolved into a variety of forms each of which is adapted and specialized to live in a unique way in a particular habitat.

Definitions: habitat, speciation, genetic drift.

B. STRUCTURAL PRINCIPLES AND DIVERSITY

1. Structural Hierarchies

Organisms are composed of small units which are grouped together to form larger units.

Definitions: structural hierarchy, small units (cells), tissues, organs, systems, organism.

2. Patterns of Structural Diversity

Living organisms are classified according to structural and functional similarities.

Definitions: patterns, structural diversity, functions.

a. Plant Kingdom
Organisms classified as plants usually have stiff cell walls and chlorophyll, and make their own nutrients.

Phylum Cyanophyta	blue green algae
Phylum Chlorophyta	green algae
Phylum Euglenophyta	euglena
Phylum Chrysophyta	yellow-green & golden-brown algae, diatoms
Phylum Phaeophyta	brown algae
Phylum Rhodophyta	red algae
Phylym Myxomycophota	slime molds
Phylum Eumycophyta	true fungi
Phylum Bryophyta	mosses, liverworts
Phylum Tracheophyta	ferns, club mosses, horsetails, pines and flowering plants

b. Animal Kingdom

Organisms classified as animals usually lack a stiff cell wall and cellulose, and have to ingest manufactured nutrients.

Phylum Protozoa	unicellular organisms
Phylum Porifera	sponges
Phylum Coelenterata	true jellyfish, corals, sea anemones
Phylum Platyhelminthes	flatworms
Phylum Nematoda	roundworms
Phylum Annelida	segmented worms
Phylum Arthropoda	arachnids, crustaceans, insects
Phylum Mollusca	snails, slugs, clams
Phylum Echinodermata	starfishes, sea urchins
Phylum Chordata	fishes, frogs, reptiles, birds, mammals

c. Protista and Monera

Classifications of organisms in each group vary according to the preferences of authors. Unicellular organisms which are difficult to classify either because they share plant and animal characteristics, or because of their differing modes of nutrition, are placed in this group. This follows Weisz (1967).

Protista	euglenoids, protozoans, golden algae, diatoms
Monera	bacteria, blue-green algae

INTEGRATED THEORETICAL SCIENCES

PHYSICAL SCIENCES

IV. ASTRONOMY

A. The Solar System

The gravitational force exerted by the sun holds together the planets and their satellites, asteroids and comets in a system.

Definitions: solar system, names of planets, asteroids, comets, satellites.

1. Planetary Motions

   All the planets revolve around the sun, which is at one focus of the solar system.

   a. Kepler's Laws of Planetary Motion (from Wyatt, 1971:178)

      i. Law of Areas
      "The line joining a planet to the sun sweeps out equal areas in equal times," i.e., the speed of a planet is greater when it is closer to the sun and slower when it is farther away.

      Definitions: equal, areas.

      ii. Harmonic Law
      "The square of the orbital period of a planet is proportional to the cube of its mean distance from the sun" ($P^2 = D^3$), i.e., the time it takes for a planet to revolve around the sun depends on its distance away from the sun.

      Definitions: period of orbit, orbit, cube.

   b. Rotation of the Planets and Satellites
   Each planet rotates on its own axis once in a certain period of time.

   The earth rotates on its axis once every twenty-four hours.

   The moon rotates on its own axis once every 28 days.

   Definitions: rotation, axis, day, night, phases of moon.

   c. Revolution of the Planets and Satellites
   Each planet revolves around the sun once in a certain period of time.

   The earth revolves around the sun once in 365 days.

The moon revolves around the earth once in 28 days.

Definitions: revolution, one year, lunar calendar, solar calendar, the seasons (spring, summer, autumn, winter).

d. Newton's 3 Laws of Motions

e. Newton's Law of Universal Gravitation

2. Planetary Composition

The composition of the planets depends upon their position in relation to the sun.

Definitions: terrestrial planets, Jovian planets, composition.

3. Earth-Moon System

a. The earth, when it is positioned between the sun and the moon, casts a shadow on the moon.

Definitions: sun, shadow, eclipse.

b. The moon, when it is in certain positions relative to the earth, exerts a gravitational pull on bodies of water of the earth's surface.

Definitions: tides (high, low).

B. Stellar Composition and Evolution

1. Stellar Composition

a. Our understanding of the composition of stars depends upon the kind of light that they emit.

Definitions: light, stars, light emission.

b. The bright light of the sun is caused by nuclear reactions in the interior of the sun.

Definitions: sun, nuclear reaction (fission, fusion).

2. Stellar Evolution

Stars evolve through various stages before they finally cease emitting light.

Definitions: evolve, white dwarf, supernova, neutron star, pulsar, black hole.

C. Galaxies

Stars, gases and dust exist in great groups which revolve in space.

Definitions: galaxy, Milky Way.

(NOTE: When children are formal operational, part of the curriculum will be devoted to relative frames of reference and the use of standard measurement of time and distance (some time measurement is included in the principles on rotation and revolution of the earth and the moon).)

V. GEOLOGY

A. The Solid Earth

1. Interior of the Earth: Internal Processes

High temperatures, pressure and molten material exist in the interior of the earth.

Definitions: layers of the earth (core, mantle, crust, atmosphere), interior, temperature, pure, molten.

a. Earth Movements
Increasing temperatures and pressures cause major movements in the earth's crust.

Definitions: earthquakes (release of elastic strain), volcanoes (release of heat and pressure), mountains.

b. Formation of Earth's Crust
Molten material that cooled rapidly formed the crust.

Definitions: crust, rocks (igneous, sedimentary, metamorphic), minerals.

c. Origin of the Continents
The continents may have drifted apart from one continental plate billions of years ago.

Definitions: continent, continental drift, continental plates.

2. Exterior of the Earth: External Processes

The surface of the earth (or crust) has been, and continues to be, gradually worn away and sculptured.

Definitions: sculptured, external processes.

a. Weathering
Rock waste is produced, partly by mechanical breaking and partly by solution and chemical decay.

Definitions: rock waste, mechanical breaking, chemical decay.

b. Erosion
The surface of the earth is destroyed when transporting agents carry away rock waste.

Definitions: erosion, transporting agents (water, ice, wind), valley, desert and coastal development.

c. Deposition
Rock waste carried away from higher levels is deposited at lower levels.

Definitions: deposition, flood plain, deltas.

B. Atmosphere of the Earth

The atmosphere above the earth is held in place by the gravitational force of the earth.

Definitions: atmosphere, gravitational force.

1. Composition of the Atmosphere

Gases float in the atmosphere above the earth.

Definitions: gases, carbon dioxide, oxygen, nitrogen gas.

2. Temperature of the Atmosphere

Solar radiation warms the atmosphere.

Definitions: solar radiation, temperature, heat.

3. Atmospheric Circulation

Air moves from an area of high pressure to an area of low pressure.

Definitions: circulation, pressure, air, wind, convection.

4. Moisture in the Atmosphere

When water is heated it evaporates into water vapor (gas) which escapes into the atmosphere.

Definitions: moisture, water, water vapor, evaporation, clouds, humidity.

5. Changes in Atmospheric Conditions

Changes of temperature, pressure and moisture conditions in the atmosphere create weather.

Definitions: changes, heating, cooling, condensation, precipitation (snow, sleet, rain), hurricanes, tornadoes, weather.

LIFE SCIENCES

VI. ECOLOGY

General principles in ecosystem, population and community ecology.

A. Ecosystem and Cyclic Use of Matter

1. Ecosystem

Exchange of materials between living and nonliving parts follows a cyclical path.

Definitions: producers, consumers, decomposers.

2. Habitat and Ecologic Niche

Place where organism lives and its status in the community depends on structural adaptations, physiologic responses and specific behavior.

Definitions: habitat, ecologic niche, structure, physiology, behavior.

3. Biogeochemical Cycles

Elements (organic and inorganic) circulate in the atmosphere and back to the environment and the organisms in it.

Definitions: water cycle, nitrogen cycle, carbon cycle, phosphorus cycle.

4. Energy in the Ecosystem

Energy is circulated in a cyclic manner so that it is neither created nor destroyed (cf., First Law of Thermodynamics).

Definitions: food chain, food pyramid, energy, cyclic.

B. Population Ecology

1. Species Population Level

Individuals of the same species compete for resources in the environment.

Definitions: species, density, birthrate, mortality, age distribution, population.

2. Interspecies Population Level

a. Interaction Between Species
Organisms living in the same environment interact with each other in many ways.

Definitions: beneficial association, negative interaction.

b. Competition Between Species
Gause's Rule: only one species exists in an ecologic niche.

Definitions: competition, ecologic niche, species.

C. <u>Community Ecology</u>

Diverse species and populations can live together in an orderly fashion.

Definitions: ecological succession, climax.

D. <u>Exemplifications of Ecological Principles in Different Habitats</u>

Organisms live in different habitats.

Definitions: fresh water habitat, marine habitat, terrestrial habitat.

Integration of the Natural Science Curriculum with the Overall Curriculum in the Anisa Model

The overall curriculum in the Anisa Model is comprised of the following separate, but interrelated curricula:

<u>Basic Competencies Curricula</u>

Psychomotor competence curriculum
Perceptual competence curriculum
Cognitive competence curriculum
Affective competence curriculum
Volitional competence curriculum

<u>Formation and Utilization of Symbol Systems Curricula</u>

Mathematics curriculum
Discursive language curriculum
Arts curriculum

<u>Higher Order Competencies Curricula</u>

Natural science curriculum (leads to technological competence)
Human science curriculum (leads to moral compentence)
Philosophical science curriculum (leads to fiducial competence)

In the overall context, the natural science curriculum is only one facet that contributs to human growth and development. The natural science curriculum can foster the development of the other curricula and vice versa. From an organismic point of view, all the components of the overall curriculum should be interconnected so that learning is an integrated experience. This is one of the unique features of this natural science curriculum.

Each of the five basic competencies may be strengthened and developed by science activities. For example, cognitive competence may be developed by science activities that focus on the use of cognitive processes such as classification, seriation, prediction and experimentation. Similarly, other activities (i.e., in the arts) which strengthen these cognitive processes also help to support the natural science curriculum.

The formation and utilization of symbols may also be enhanced by science activities and vice versa. Mathematical understandings of basic concepts of number, space and time can become an exciting and challenging experience when integrated with science activities. Discursive language, vocabulary, grammar and reading can become more meaningful to the child when interrelated with other experiences such as natural science. The arts and aesthetic uses of language can also be developed by using themes or ideas from natural sciences.

As discussed in Chapter III, technological competence cannot be considered apart from moral and fiducial competence. The relationship between natural science and the social sciences (morality, ethics, psychology, anthropology and sociology) and the philosophical sciences (religion and philosophy) require discussion and investigation far beyond the scope of this dissertation. The basic principles for their integration, however, have been presented. What is needed now is a systematic application of the organismic principles in filling out the details.

The next chapter will discuss how the proposed framework for the natural science curriculum presented in this chapter can be implemented.

CHAPTER VI
IMPLEMENTATION OF THE NATURAL SCIENCE CURRICULUM: GENERATING LEARNING EXPERIENCES

Implementation of the natural science curriculum will necessitate the developmental sequencing of process and content goals, planning appropriate experiences for children so that the goals can be achieved and identifying the kinds of integrations that can be made with the overall curriculum. Developmental information that was presented in Chapter IV on the nature of children's scientific thought can now be applied to the components of the framework of the natural science curriculum as outlined in Chapter V.

Careful sequencing of the content component of the natural science curriculum is necessary if children are to learn information about the physical environment. Researchers report that children can be introduced to the fundamental ideas in natural science if the information to be learned is developmentally-sequenced and accompanied by materials that children can manipulate themselves (Inhelder, in Bruner, 1960; Victor, 1971). The laws and principles that were identified in Chapter V can be presented to children in simplified (but not trivial) forms that match their developmental levels. This means that young children can be introduced to the necessary, pre-requisite experiences that will make it possible for them to understand more fully a given law or principle at each of several later stages, until it is finally understood fully.

The natural science curriculum that I am proposing rests on the idea that developmental sequencing of content (so that children progressively encounter similar but more complex ideas) can be organized in a spiral. According to Bruner (1960), a natural science curriculum can be developed so that certain basic ideas can be examined repeatedly and gradually built upon to achieve more complex understandings. Bruner states that if students are to study physics or biology later in high school, there is no reason why these subjects should be a totally new experience and present a block to learning. With careful planning and the application of developmental principles it is possible to provide certain basic ideas when children are young so that they can be prepared for later studies.

Steps in Planning Developmentally Sequenced Experiences to Achieve Technological Competence

The planning of developmental sequences of learning experiences can be guided by the theoretical framework that was presented in Chapter V. Ultimately, such planning will depend on classroom teachers, their knowledge of and previous experiences in, and attitudes towards natural sciences. The issue of adequate teacher preparation programs in science education is too vast and complex a subject to be addressed in this dissertation (see Carney, 1977).

However, the reason for the theoretical framework presented in the previous chapter is that it will allow teachers to be more generative. Rather than being attached to specific activities for all the children in the class, teachers can be guided by the theoretical principles of development and curriculum to meet the needs and interests of children of varying abilities. To achieve success in planning appropriate sequences of learning experiences in natural science, teacher preparation programs will need to expose teachers in a systematic manner to the major laws and principles of natural science.

It should be made clear at the outset that there is no "one specific way" of planning science activities for children. The direction of the planning process may be dictated by the purposes that the teacher has in mind or by what the children would like to do. Teachers will have to be flexible and gain the most mileage out of any activity, be it science or moral education. From an organismic perspective, all of life is the ground for learning and any form of narrow compartmentalization of subjects will tend to suppress the full development of the child. To write about "a natural science curriculum," then, may seem to be a contradiction. However, what should be emphasized is that the natural science curriculum is inextricably connected to the overall curriculum and this will be reflected in the planning process.

The attainment of technological competence may be facilitated by following the general guidelines provided in the proposed framework in Chapter V. There are several possible starting points for developing a natural science curriculum. However, in emphasizing the attainment of technological competence, the following three starting points may be the most useful: (1) focusing on content to be learned; (2) focusing on processes to be strengthened and (3) focusing on some application. In most cases, process and content will be fused as it is not possible to teach some content without some process and vice versa.

The sequences of steps that follow from each of the starting points mentioned above will now be presented. The reason for outlining all three sequences is to illustrate how the pitfall of adhering too rigidly to one linear set of steps in planning experiences can be avoided.

I. Focus on Content

A. Select the law or principle (content) to be learned.

B. Identify the developmental levels of the children to be taught (i.e., pre-operational, concrete operational, formal operational).

C. Break down the law or principle into concepts that are appropriate for each developmental level (i.e., break-down into content goals).

D. Identify the specific processes to be strengthened and state the accompanying process goals to be achieved in accordance with each developmental level.

E. State the learner objectives for each developmental level, i.e., statements which are fusions of specific process and content goals which provide evidence for the achievement of the goals.

F. Identify the symbol systems to be developed as they relate to the content to be learned at each developmental level.

G. Outline the points of integration of the content with the overall curriculum.

H. Describe the learning experiences that children will engage in to achieve the goals outlined above.

II. Focus on Process

A. Identify the developmental levels of the children to be taught.

B. Identify the processes to be strengthened and state the accompanying process goals to be achieved at each developmental level.

C. Select the law or principle to be learned.

D. Break down the law or principle into concepts that are appropriate for each developmental level (i.e., into content goals).

E. State the learner objectives for each developmental level, i.e., fusion of process and content goals.

F. Identify the symbol systems to be developed as they relate to the content to be learned at each developmental level.

G. Outline the points of integration of the content with the overall curriculum.

H. Describe the learning experiences that children will engage in to achieve the goals outlined above.

III. Focus on Application

A. Select the area of application, e.g., a problem or issue to be solved such as pollution, building shelves, developing a vegetable garden.

B. Identify the laws or principles that are related to the selected area of application.

C. Identify the developmental levels of the children to be taught.

D. Break down the laws or principles into concepts that are appropriate for each developmental level (i.e., into content goals).

E. State the learner objectives for each developmental level, i.e., fusion of process and content goals.

F. Identify the symbol systems to be developed as they relate to the content to be learned at each developmental level.

G. Outline the points of integration of the content with the overall curriculum.

H. Describe the learning experiences that children will engage in to achieve the goals outlined above.

Example of a Sequence of Learning Experiences in Natural Science

To make the process of planning learning experiences explicit, a more detailed elaboration will be presented in this section, using the steps A-H outlined in the sequence that started with the selected law or principle, i.e., Focus on Content (see page 191).

Since the emphasis of this dissertation is on elementary school science, only two cognitive developmental levels will be discussed in detail, namely, the preoperational stage (about 3-5 years) and the concrete operational stage (about 6-11 years).

I. Focus on Content

A. Select Law or Principle

I have selected Huygen's Principle of Wave Propagation from the area of Physics. This is a general principle about the transmission of a disturbance (wave motion) through a medium and/or space, and as such it applies to water waves, sound waves and light waves. In the specific example to follow, I am going to focus on Huygen's Principle as it relates to the phenomenon of sound.

Huygen's Principle of Wave Propagation may be defined in the following manner:

> A wave is a disturbance that is propagated through space and/or some medium.

B. Developmental Levels of Children

A diagnosis of the children's stages of cognitive development will indicate different levels of mental functioning, i.e., pre-operational and concrete operational levels. Whatever content and process goals are established will have to fit these developmental levels.

C. Breakdown of Principle According to Developmental Levels (Content Goals)

Since Huygen's Principle is so complex, the task is to find out what concepts essential to this principle as it relates to sound can be comprehended by children at the pre-operational and concrete operational levels. This means that the principle has to be broken down into simpler concepts to fit the developmental levels. In this example, I will present the concepts for the formal operational stage as well, so that continuity of the levels of complexity may be seen.

The concepts of "wave" and "propagation" are very abstract and far too difficult for young children to comprehend. However, simple analogies with general types of waves can be introduced, e.g., water waves, skipping rope waves, slinky waves. When children are at the earlier developmental levels, the connection between general waves and sound waves should not be made as this will only serve to confuse them. However, when they can think in a more abstract manner, the connection can be made.

It should be emphasized that there is great variation in the levels of understanding even within one developmental stage. Thus, the statements of content goals will have to match the developmental needs of children, say at the early, middle and late pre-operational stages.

The following general content goals state what concepts children should know about Huygen's Principle and Sound at different developmental levels:

Pre-operational Stage

Children should know that:

1. Many different kinds of waves can be created, e.g., waving arms, streamers, throwing stones into water.
2. When objects collide or hit each other, they shake (vibrate) and produce sound.
3. There are many different kinds of sounds that we can hear with our ears.

Concrete Operational Stage

Children should know that:

1. Sound is caused by the vibration of objects.
2. Certain parts of the ear vibrate and hearing then occurs.

3. A disturbance in a tank or pool of water moves outward in the form of waves, such that a large disturbance creates many, big waves and a small disturbance creates fewer, little waves.
4. Sound can be reflected off objects.
5. Sound has different dimensions, each of which can vary: pitch, quality (timbre), loudness and duration.

Formal Operational Stage

Students should know that:
1. Sound is created by a disturbance that moves outward in the form of a wave in some medium such as air or water and not in a vacuum.
2. Water particles and particles that create sound differ in their direction of vibration, i.e., water particles vibrate vertically in the same place, whereas particles that produce sound vibrate horizontally in the same place.
3. The pitch of a sound is determined by the number of waves that pass a certain point in one second (i.e., notion of frequency, wave-length).
4. The speed of sound is determined by the medium in which the wave is being propagated.
5. Sound waves transmit energy to the surrounding medium.

(At the formal operational stage, complex ideas on sound and wave motion can be introduced, since abstract concepts can now be processed.)

D. Processes to be Strengthened and Process Goals

Diagnosis of the developmental levels of children gives an indication of the kinds of cognitive processes that are being internalized. Different processes will be strengthened at the various developmental levels. Again, there is a great variation in what children are capable of understanding, even if they are all pre-operational or concrete operational.

The following process goals related to sound are stated in terms of what children should be able to do at a particular developmental level:

Pre-operational Stage

Children should be able to:

Psychomotor processes:	manipulate materials; vocalize sounds
Perceptual processes:	discriminate auditory figure and ground; perceive loudness and the localization of sound.
Cognitive processes:	classify; make simple predictions; perform simple tests (or "experiments"); make simple comparisons; differentiate simple cause and effect relations.

Concrete Operational Stage

Children should be able to:

Psychomotor processes:	manipulate materials; vocalize sounds
Perceptual processes:	discriminate auditory figure and ground; perceive loudness, pitch, timbre, duration and localization of sound.
Cognitive processes:	classify; seriate, conserve; formulate simple hypotheses; make simple predictions; perform simple experiments; make comparisons; draw conclusions; and differentiate cause and effect relations.

E. Statement of Learner Objectives

Learner objectives are operationalized statements which constitute fusions of specific process and content goals. Since an objective serves the purpose of determining what evidence is acceptable to the teacher that certain goals have been achieved, then it has to be stated in the form "Children will be able to" actually do something that is observable. To know whether a content goal has been achieved, the child will have to perform some action to let the teacher know that the content has been assimilated and understood. A process goal by definition means that a child will perform some action from which the internalization of a process may be inferred.

Since there are numerous learner objectives that can be listed, I will just present two examples that show the fusion of process and content goals:

Pre-operational Stage

> Children will be able to produce and describe 6 different sounds by using 6 different kinds of materials.

Concrete Operational Stage

> Children will be able to set up various simple experimental situations where the vibration of different materials can be observed and matched on the dimension of pitch. They will be able to explain what they had to do to make the pitches match.

F. Formation and Utilization of Symbols

Information about Huygen's Principle, as it relates to sound, will be conveyed largely through the use of words (language) and mathematical symbols. When children are at the pre-operational level, mathematics will not play a great part, that is, in terms of number relations. However, pre-requisite mathematical processes like classifying or grouping will be strengthened, and the understanding of words related to sound can be enhanced. Simple quantitative relationships about sound can be introduced at the late concrete operational stage, e.g., frequency graphs and measurements.

The following statements are some of the objectives to be achieved in the formation and utilization of symbols:

Pre-operational Stage

Children will be able:

Mathematics:	to classify sounds (group into a set) according to one dimension at a time.
Language:	to label sounds. to describe different sounds.
Arts:	to compose simple rhyming sounds. to follow simple rhythms (e.g., clapping, tapping).

Concrete Operational Stage

Children will be able:

Mathematics:	to measure distances across which sound travels. to plot frequency graphs, initially on general topics.
Language:	to explain the meaning of words related to sound, e.g., vibration, loudness, pitch, direction, source, etc. to describe in words the moods created by music. to write stories on sounds.
Arts:	to describe patterns in sounds.

G. Integration With the Overall Curriculum

Within the theoretical framework of the Anisa Model, the natural science curriculum is integrally connected to other areas of learning, such as mathematics, language, arts, cognition, perception, etc. Natural science is also closely related to the human and philosophical sciences. When children are young, the emphasis will be more on the interrelationship between sound and its effects on people and society (human sciences), rather than on abstract philosophical issues. Even within the natural sciences, integrations can be made between sound (physical science) and the life and earth sciences.

Examples of the kinds of integrations that can be made now follow:

Pre-operational Stage

Human sciences:	understanding the value of sounds, speech, and music in the life of man.
Life sciences:	understanding the role of sounds in animal life.

Concrete Operational Stage

Human sciences:	understanding the vital role of speech in human life i.e., in communications. understanding the role of music in civilization. understanding the concept of noise pollution. understanding the relationship between sounds and the creation of fear in people. understanding how knowledge of the principles of sound transmission have affected our lives, e.g., radios, televisions, telephones, etc.
Life sciences:	understanding in a simple manner the working of the ear and the vocal cords. understanding the role of sound in the animal world, e.g., echolocation, communication, calls in mating, etc..

Earth Sciences: understanding how knowledge of principles of sound transmission can assist in the detection of earthquake centers, location of submerged objects (sonar), etc.

H. Interactions or Learning Experiences to Achieve the Goals

The learning experiences or activities that are planned by the teacher should meet the goals that are to be achieved. In some cases, the whole class may do the same activity and at other times, groups of children may work on different activities. There will also be instances where a child may wish to work alone on some activity, or it may be that a particular child needs individual attention, in which case specific activities will have to be planned. Knowledge of the cognitive, as well as the emotional and social needs of the children will be an immense asset to the teacher in planning activities in natural science.

Learning experiences, such as the following, can assist in children's understanding of sound and wave concepts. These are general activities presented here as examples. However, when a teacher adopts a specific goal, specific activities will be planned to meet that goal directly.

Pre-operational Stage

1. Provide children with opportunities to create waves of different types, e.g., movement activities, tubs of water, or field trip to a pond.
2. Provide a variety of materials that children can experiment with and identify objects that shake to produce sound.
3. Take field trips to different settings so that children can hear a variety of sounds and identify the sources of the sounds, e.g., go to a large kitchen, to a game park, a bird sanctuary, stand safely near a road, etc.
4. Place different types of sounds on a casette tape and have children listen and identify them.
5. Encourage children to play with simple musical instruments and identify sounds that they enjoy and do not enjoy.
6. Invite musicians to come to the school to play and explain about musical instruments to the children.

Concrete Operational Stage

1. Provide opportunities for children to set up various simple situations in which they can identify the vibration of objects and describe the sounds created.
2. Provide a simple model of the ear so the vibrating parts can be observed.
3. Provide opportunities for children to create an indoor or outdoor situation where they can investigate and observe the motion of waves, e.g., indoor water tank.
4. Children can play with a "Slinky" (a walking spring) and observe the wave-like motion.
5. Allow children to describe and go out and locate places where sound is reflected and echoes are created.
6. Provide materials and musical instruments that children can play with and create sounds of different pitch, loudness, quality and duration.
7. Take children on a bird-watching trip so that they can locate the birds that are singing.
8. Children can learn the conservation of pitch while varying the quality of the sound--they can use a xylophone, metallophone, recorder and a human voice.

9. Provide pieces of music (recordings) or pieces that children create for the analysis of moods, atmosphere, rhythm, etc.
10. Children can undertake individual or class projects on noise pollution, e.g., they can visit an airport, interview people, etc.

The detailed elaboration just presented was developed by selecting a particular principle as a content goal, and then following through a predetermined sequence of steps. If certain processes of scientific method were to be taught, then the sequence entitled "Focus on Process" (see page 192) would be followed. In both cases, the actual learning experience or activity constitutes a fusion of some principle and some processes. While it is impossible to separate process and content, it is possible to emphasize one more than the other.

Starting with an area of application (i.e., tuning a violin, dealing with a real problem in living) presents an opportunity for making many integrations at the same time. Rather than just focusing on one principle in physics or one law in biology, the selection of a problem like pollution will include many principles from physics, chemistry, biology, geology and ecology. Once the key principles have been identified then the sequence of steps outlined in the detailed elaboration can be followed. In some instances the area of application may not be very broad and in this case one or two major principles may be isolated, e.g., in the building of shelves, principles relating to force, gravity and balance may be learned (together with many mathematical concepts).

One of the most important aspects of the implementation of the natural science curriculum as proposed in this dissertation is that teachers will be involved in actually building the curriculum. Essentially, the laws and principles, and the statements of the content and process goals will be outlined in simple, understandable language by the curriculum specialist so that teachers can work with the ideas. Teachers will then take the content and process goals and generate their own learner objectives and learning experiences to meet the developmental needs of the children. A resource file of activities should be organized so that teachers will have easy access to a variety of ideas of what they can do to achieve the goals of the natural science curriculum.

My purpose in this dissertation has not been to list a set of activities or to present a fully developed natural science curriculum. What I have tried to do is present a basic framework that will enable curriculum specialists and teachers to work together in generating and implementing a comprehensive natural science curriculum. In this way the organic nature of the process will be insured.

The next chapter presents the distinguishing features of an organismic approach to science curriculum development.

CHAPTER VII
DISTINCTIVE FEATURES OF AN ORGANISMIC APPROACH TO SCIENCE CURRICULUM DEVELOPMENT BASED ON THE ANISA MODEL

I would like to state at the outset that the framework that I have proposed in this dissertation is only one alternative approach to the organization of a natural science curriculum. This is not intended to mean that the efforts exerted over the last decade in science education have been without merit and value. It is reasonably clear that as the complexity and the sheer volume of our knowledge increases, the necessity of making broader syntheses and integrations becomes vital, especially in the educational process. My intention has been to draw on the knowledge of the past and try to present one possible approach that could assist in answering some of the issues in science education, particularly in relation to our newly-emerging world view.

Comparison of the Proposed Framework for a Natural Science Curriculum with Other Science Curricula

The distinctive features of an organismic approach to science curriculum development can be most adequately assessed by comparing it with the science curricula that were developed during the sixties. Components of the framework presented in Chapter V, namely, process and content goals, formation and utilization of symbols and types of interactions, will be compared and contrasted with three major science curricula: The Science Curriculum Improvement Study, Elementary Science Study and Science--A Process Approach.

I. Process and Content Goals

Many of the new curricula developed in the sixties were instrumental in breaking away from the traditional nature study approach and rote memorization techniques involved in science study. Processes of discovery and cognitive reasoning were emphasized together with a more systematic organization of the most important ideas in natural science that could be learned by children. However, these curricula have not emphasized process and content goals equally. For example, Science--A Process Approach, as its name implies, focuses on the development of processes which can be transferred to other areas of study. Such a goal is vital if children are to become competent learners and take charge of their own learning. However, the content of natural science is equally important if knowledge is to be generalized and utilized in other situations. In S-APA, content is not as important as process. The Science Curriculum Improvement Study emphasizes the learning of content to achieve scientific literacy. Processes are not neglected, but they do not constitute the primary focus. The Elementary Science Study curriculum developers recognize the important of organizing a curriculum around the developmental levels of children. However, content and process goals are not presented in a systematic manner.

In the framework for the natural science curriculum based on the organismic view, process and content goals are both emphasized, and the means of achieving them integrated in the interaction component are spelled out. The process goals are in fact more extensive than in the other science curricula. Cognitive processes are emphasized but not to the exclusion of other developmental processes. Each interaction with the physical environment implicates psychomotor, perceptual, cognitive, affective and volitional processes, and these implications are exploited to enrich the natural science curriculum.

The content goals in the proposed framework were presented in a detailed manner for two reasons. (1) Processes, if they are to be strengthened, must be applied to some content. From an organismic point of view, comprehending the relationships between and amongst events is the key means of understanding the physical environment. The laws and principles which express these relationships and which form the basis and content of the natural science curriculum were therefore identified in detail. Focusing on laws and principles rather than on activities in natural sciences facilitates the generalization of content.

According to Bruner (1960), the knowledge of the structure of a subject is vital as it calls for the identification of the most fundamental ideas that will be included in the curriculum. If the fundamentals are comprehended, then later understandings can be built on them. The point is that the fundamentals, verbally stated, comprise content and can be memorized by rote. To understand or comprehend fundamentals, however, requires that related processes be developed as well. Without the integration of process with content, there will be little generalization and content will be easily forgotten: rote memory can take a child only so far.

Learning a general idea is powerful because it can form the basis for recognizing and applying the idea in a similar but new situation (generalization). Bruner claims that the "teaching of specific topics or skills without making clear their context in the broader fundamental structure of a field of knowledge is uneconomical" (1960: 31). The reasons for this are that students cannot generalize what has been learned and that the sense of intellectual excitement is lost without a grasp of general principles.

To avoid the danger of just focusing on the logical structure of natural science, the framework presented in this dissertation relies heavily on knowledge of how children's scientific thinking develops. A great deal of work remains to be done in this area, but the developmental knowledge that we do have can be used in a more fruitful manner to present the fundamental concepts of natural science to young children in appropriate sequences. Making the connection with children's developmental levels will avoid boring them on the one hand or setting them up for a guaranteed failure on the other.

II. Formation and Utilization of Symbols

The development of symbol systems (mathematics, language, the arts) that convey information about the world does not receive a clear emphasis in previously developed science curricula. Mathematics is considered to be a most important tool in science and therefore receives more attention than language and the arts in these science curricula. In the framework presented in Chapter V, mathematics, language and the arts are integral parts of the overall curriculum and also play a definite role in the natural science curriculum. Mathematics is used to convey quantitative information; language conveys descriptive information (words), and the arts are used to develop aesthetic sensitivity and appreciation of patterns and order in nature.

III. Interactions to Achieve the Goals of the Curriculum

In many of the previously mentioned science curricula (S-APA, SCIS, and ESS), learning experiences are described for all children to engage in if they happen to be in a particular grade and in a certain age group. Yet age levels are not the appropriate criterion for grouping children for instructional purposes. The reason for the detailed description of science activities is probably based on the assumption that teachers are not familiar enough with the concepts of natural science to plan their own activities in accordance with developmental levels. It is also probable that by not preparing teachers to teach on the basis of a framework for a natural science curriculum, the tendency is to become attached to specific activities assigned to age levels. The students are then left with a "bits-and-pieces" idea of natural science.

Teachers prepared in the framework for the natural science curriculum that is based on an organismic perspective are exposed to the fundamental laws and principles of natural science in a concrete and meaningful way together with detailed developmental information on children. The activities that they plan will fit the children and in addition be drawn from sources related to problems and issues that face man. These sources would be the applied sciences such as agriculture, engineering (highway, bridge, dam construction, etc.), animal husbandry, horticulture, etc. A focus on such applied fields would not have to be a drain on teachers, since this would provide a wonderful opportunity of utilizing community people who are trained in a variety of fields. They could be invited to present and discuss the basic principles of their work in a manner appropriate for children.

Applied sciences are such a pervasive force in our lives that they should be included in the natural science curriculum. The definition of technological competence that was discussed in Chapter III reflects the concern for including the notion of applications in interactions with the physical environment. The importance of the inclusion of the applications of scientific knowledge is emphasized by Hurd. He states that many of the science curricula of the sixties excluded applications in their schemes. However, there is a great need to involve children in understanding the role of science and its relation to human welfare. This can be accomplished by ". . . using its concepts to attack the persistent problems of human experience, and stressing its potential for improving the 'quality of living'" (Hurd, 1975:27).

From an organismic perspective, the relationships between knowledge and its application are vital since they reflect the reality of living.. For Whitehead, the crucial aspect of education is not the acquisition of inert ideas but "the art of the utilization of knowledge" (1967b:4).

Concluding Remarks

From the discussion in the previous section, it should be evident that an organismic approach to science curriculum development has certain distinctive features that are missing in the numerous other science curricula. The approach presented in this dissertation is not a wholly radical departure from previously developed schemes. It does, in fact, incorporate elements from many of the other science curricula; but it also adds significant new features that can address the issues of relatedness, integration and wholeness--all of which are necessary if science education is to be a meaningful experience for children.

A major focus of this dissertation has been the presentation of the philosophical and theoretical framework of the Anisa Model, the central thesis of which is the actualization of human potential. In the Anisa Theory, the natural science curriculum occupies a central role with a clearly defined overarching objective which is the attainment of technological competence. The natural science curriculum is also <u>integrally</u> connected with other areas of learning such as cognition, perception, volition, mathematics, language, the arts, human and philosophical sciences. The organismic nature of the type of framework that I am proposing is captured in the following statement by Whitehead:

> The solution which I am urging, is to eradicate the fatal disconnection of subjects which kills the vitality of our modern curriculum. There is only one subject matter for education, and that is Life in all its manifestations. Instead of this single unity, we offer children--algebra, from which nothing follows; geometry, from which nothing follows, science from which nothing follows; history, from which nothing follows, a couple of languages, never mastered; and lastly, most dreary of all, literature, represented by plays of Shakespeare, with philological notes and short analyses of plot and character to be in substance committed to memory. Can such a list be said to represent Life, as it is known in the midst of living it? (1967b:6-7).

Disconnection between the developmental levels of the children and the demands of the curriculum is equally fatal. I have tried to show how the natural science curriculum I am proposing, because of its genetic epistemological basis, can be tailor-made to suit the developmental needs of children so that the actualization of their potential can be continually sustained and nourished. To accomplish this goal fully calls for renewed efforts in the training of teachers, who are not only exposed to the fundamental ideas of natural science and developmental knowledge, but who are also incorporated in the very process of curriculum-building. Teachers are the people who are in closest touch with the developmental needs of children and as such, must become an integral part in the organic evolution of the natural science curriculum.

There is one last point that I feel has been an important focus in this dissertation. I have stated that the overarching objective of the natural science curriculum is the formation of material values upon which rests the attainment of technological competence. As children interact with the physical environment, they will learn certain patterned ways of using their energy. All such patterned uses of energy (i.e., material values) are not equally acceptable. Some are more effective than others as determined by two criteria: (1) do they insure survival? and (2) do they lead to the kind of technological competence that can improve the quality of life? It therefore becomes crucial that the formation of material values should not be left to chance. Material values that meet these two criteria should be developed in children when they are young so that there exists a deep regard for the pursuit of truth in understanding the operation of the physical environment, a heightened awareness of the need to protect the environment and its resources, and a sincere concern for the problems and challenges that face mankind. It is upon such material values that the attainment of technological competence rests. The hallmark of learners who are technologically competent is that they will understand, discover and apply their knowledge of scientific laws and principles to effect changes in, and gain control over, the physical environment. When technological competence is subordinated to moral and fiducial competence, there is reasonable assurance that the quality of life on this planet can be continually improved for all human beings.

In terms of the framework that I have proposed for a natural science curriculum, there are many issues yet to be resolved. Teacher preparation programs in natural science, evaluation instruments that can measure the process of learning, more complete developmental knowledge about how children learn to think, and diagnostic instruments to assess developmental levels more accurately are some of the issues that will have to be worked upon in the years to come.

It is my conviction that the role of natural science in the lives of children is of paramount importance. Every attempt is worthwhile if it serves to assist children to understand the physical world in which they live so that they can make a contribution to improving the quality of life.

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